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Efficiency in Lasi & Idea glued glazing system maintenance

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Abstract

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Lasi & Idea is a SME based in Vantaa, Finland. The company provides services for balcony glazing system maintenance. Glued glazing system maintenance is a service, which produces most of the firm's revenue. Lasi & Idea is a beginner in its Lean journey. Before this research, the staff of Lasi & Idea have gathered twice for a Kaizen event. The seed of interest was planted into the management, with the author being one of the members of Lasi & Idea board.

The goal of this thesis is to provide in depth knowledge of Toyota Production System philosophy and to produce a value stream map from the glued glazing maintenance process. The value stream map is also the product (PO) of this thesis.

Thesis scope is in the glued glazing maintenance process. The process starts from removing the glasses and end after re-installing the maintained glasses. This thesis does not focus in the supply chain of Lasi & Idea, but does involve JIT purchasing in depth the author thinks it supports the process flow of glued glazing maintenance. Similarly, it does overlap into the project management of Lasi & Idea as Heijunka, a Lean levelling tool would affect the process stability in project environment.

The research method of this thesis is quantitative. The data was acquired by filming a maintenance process in Vantaa, Finland. From the clips, every activity second was categorized to seven wastes and to the appropriate process step. Qualitative observations were made as well and attached to the activity. Clips were captured in June 2017, while the thesis plan had been made spring 2017. The conclusions of the thesis were written in November 2017.

Quantitative data analysis points 4 major waste groups and reveals the unevenness of the process in terms of high takt time variance. The newly acquired data allows Lasi & Idea to implement suggested improvements, for example implementing JIT, 5S, Kanban tool. New process metrics are introduced as well. The suggestions provide valuable information to start building a sustainable flow efficient glued glazing system maintenance.

The conclusion reveal that the glued glazing maintenance is resource efficient. Designed to bring the work to the resource. The design is also built to handle large batches. This is opposite from Lean, as in Lean thinking the work for the customer should be brought as close to the origin and focus moving a single flow unit with a minimum waste. The result was 31.8% of value adding activity with a small 5 glass batch. There was no flow present. Small work in process inventories were created between all the process steps. By minimizing batch size and conducting a Value Stream map many hidden problems may become visible.

Keywords
Lean, value stream mapping, JIT, Heijunka, Kanban, Kaizen.

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1 Introduction

Resident of the apartment receives a note. “Dear resident. Your balcony glazing will be removed 11th of May for maintenance. The maintenance has been ordered by the owner of the glazing, the housing board. We hope that that you will grant us free access, and the balcony will be empty of your belongings. Projected maintenance time is three (3) working days…” (Lasi & Idea service letter 2017).

Many activities take in place from receiving a note like above to the completion of the process chain. The first chapter presents the background information of the project oriented thesis and the introduction of the case company. Primary goal of the project is to produce a Value Stream map that allows Lasi & Idea to start measuring meaningful process efficiency metrics. The secondary objective is to create a deep knowledge base, in form of this thesis and to enable the first firm steps of Lasi & Idea´s Lean journey. Project tasks (PT) are conducted with agile sprints, starting from defining applicable theory and conducting a Value Stream map. The data is analysed in chapter four and concluded in chapter five. The appendices will contain the product in pictures. The author suggests readers interested in Value Stream mapping to carefully familiarise oneself with Lean philosophy and Lean thinking beforehand.

1.1 Background

Installation and selling of balcony glazing systems were the core function when the company was established. The market has been extremely saturated since 2007, where especially the Business to consumer demand drastically dropped. Many significant players have been forced out of the market. The installation service for the new balcony glazing systems have been increasingly provided by workers from low-cost countries. The profit margins have been very slim. Most of these manufacturers have been fighting hard to make profit. Competing in this sector was seen pointless with the resources Lasi & Idea have. Most of the balconies have been glazed already in the standing buildings and almost all the new production has the balconies glazed during last phases of construction.

Finton balcony glazing, a brand that was heavily installed between years 1995 to 2007, in this thesis, serves as an exemplary case. This, as well as several other balcony glazing products have been built by fastening the glass to the aluminium frames with a glue. The frames connect the glass to the sliding profiles, allowing each panel to move sideways and enable 90 degrees opening inside from selected point. The glue that fastens the glass to aluminium lasts approximately 10 years. This is because of the glue wearying by UV-

radiation and temperature change. Lasi & Idea has provided the uninstallation of the glazing, transportation to the workshop and back, the chemicals, mechanical cleansing of the clue residues, warehousing and re-installation. The glue and the gluing process has been studied with an engineer company to provide best in market durable hold and gluing procedure. The need for the maintenance is based on the safe usability as the owner, many times the housing board, do not wish to take the risk of these glue problems resulting in falling glasses from balconies.

To improve the labour-intensive, multi-step process Lasi & Idea is delighted to commission the author and to grant full support for the study. Lasi & Idea management assumes that the efficiency of the process could be reconfigured, and additional tools acquired to support efficient, more profitable, high-quality process output.

The output quality is of high importance as the housing board often decides to order a pilot where the share owners receive the service, and in the end, pay it as a monthly maintenance fee. There are often two to four stakeholders, receiving the value of the service; Housing board, property manager, general maintenance and the apartment owner or the rental. Ideally the glazing should stay removed for as little time as possible, leaving the cover off from the possible weather damage to the habitant's balcony belongings. Added to the previously mentioned, the maintenance process should produce long lasting solution and safety to the customer. Lasi & Idea feels there could be benefits to re-examine the process of Glued glazing system maintenance.

The author of this thesis is honoured to represent Lasi & Idea in this thesis study. The author's specialization in supply chain management gives the needed background to support a successful study, motivation to learn deeper insight into Lean philosophy and how to implement theory into everyday process management of the case company. This is expected to be challenging and fruitful.

1.2 Project Objective

The focus of this thesis is to enable Lasi & Idea to produce an improved and standardized framework for internal supply chain process management, the glued glazing system maintenance. Project objective (PO) is a detailed Value Stream map, providing necessary quantitative data and perception for efficient, high quality, customer oriented service.

Achieving the objective (PO) in a clear and structured manner that pleases all the stakeholders is a key element of this thesis. Deep understanding of Lean is necessary as Lasi

& Idea plans to initiate its future learning program based on this thesis. The project is divided in project tasks (PT) and separated in five focus zones which do not appear in order of importance, but all are vital in producing the desired results.

PT 1. Thesis planning and project management
PT 2. Creating applicable theoretical framework
PT 3. Project and data management methods
PT 4. Analytics and suggestions
PT 5. Conclusions

Table 1 presents the project task, purpose, theoretical framework and desired outcome for each project task.

Table 1. Overlay matrix

Project task (PT)	Purpose	Theoretical Framework	Outcome	Report Chapter
- Thesis planning and project management (PT1)	- Keep thesis focus concentrated as planned	- Project management tools - Agile - Lean	- Thesis boundaries	- Introduction 1.
- Creating applicable theoretical framework (PT2)	- To select most suitable, best in practice tools and models	- Philosophy - Kaizen - Muda, Mura, Muri -Heijunka -JIT -Kanban -Takt time -5S -Flow -Visual factory	-Structured, logical and understandable theory building of the case - supporting creating and analysing project objective (PO)	- Theoretical Framework 2 - Analysis 4
- Project management methods and	- Understanding existing process flow	- Value stream map - KPI - Kaizen	- Detailed and easy to understand capturing of the existing flow.	- Theoretical Framework 2 - Analysis 4

mapping of existing process flow (PT3)			- Management methods to provide trustworthy data	- Project and data management methods
Data analytics (PT4)	Understanding the data provided by the Value Stream map	- Continuous flow - RCA - JIT - Value analysis - Pareto Analysis	- Results of to be analysed	- Analysis of glued glazing system maintenance 4.
- Establishing platform for future improvements and conclude thesis (PT5)	- To build a platform for future improvement and finalize the product.	- Kaizen - Gemba	- Value Stream map presented (PO)	- Future steps and conclusions 5.

1.3 Project Scope

This project does not intend to examine the competition in the same field of industry. Neither will it analyse the external supply chain quality beyond brief layout of what is being sourced from where and how it suits the project goal. Viewpoint of this study is to maximize in-house processes of glued glazing maintenance and to enable the service of glued glazing system maintenance to be able to create maximum value for the customer(s). In this study, the customer is mostly the resident. However also the general maintenance company or landlord, who acts as a technical specialist or takes a place of project leader for the housing board, does create certain demands.

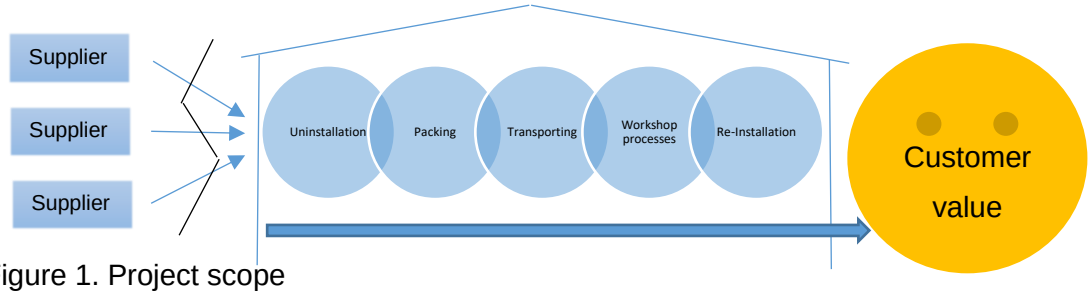


Figure 1. Project scope

1.4 International Aspect

Lasi & Idea have established an internationalisation plan to enter Russian and Estonian market, mainly to St. Petersburg and Tallinn. The process model is expected to work as in the handbook, but needs to be revised. The Glued glass system service handbook should be revised, if the culture influence changes with the customer, but at least the core of the handbook is expected to be used as developed here. Local laws and regulations must be implemented into the maintenance project.

1.5 Benefits

Short term expectation is to start building a continuous learning organisation for Lasi & Idea. Also for Lasi & Idea, it expects to receive trustworthy data as it will be used to improve glued glazing maintenance process efficiency. With the improved framework, in long term, Lasi & Idea plans for easier scalability of the glued glazing system maintenance, to be able to access into larger international projects. The benefits for the customers of Lasi & Idea in need for glued glazing system maintenance are expected to experience increased value.

Besides the commissioning company and its customers, the study is expected to deliver value for start-ups looking to launch manufacturing service that creates as much value towards the customer needs. The author hopes that this project oriented thesis is a valuable study for Lasi & Idea, but also for other SME entrepreneurs, willing to improve process quality.

The author of this thesis is honoured to represent Lasi & Idea in this thesis study. The author's specialization in supply chain management gives the needed background to support a successful study, motivation to learn deeper insight into Lean philosophy and how to implement theory into everyday process management of the case company. Finally, the thesis process from the beginning to the completion is expected to teach author more project management skills and managing quality through carefully selected tools and models. This is expected to be challenging and fruitful.

1.6 Case Company and field of industry

Lasi and Idea has been founded 2013. The best revenue year has been 238 000 €. The company have 2-6 employees. Employees have been hired, or the work outsourced, based on the project. Since 2016 Lasi & Idea has been focusing to offer maintenance for

the existing glazing. Some yearly maintenance contracts have been established. Meanwhile several large companies like Lumon have established their own maintenance. Until today, the maintenance service of large competitors has been offered for their own glazing brands only.

Lasi & Idea's IDEA HUOLTO service have been offered for all glazing brands. The most noticeable market demand has been for the glazing brands of companies that have gone bankrupt during the beginning of 21st century. Maintenance of these brands have been neglected because of the lacking spare parts. Lasi & Idea has been able to produce these spare parts in small numbers by 3D printing. While tackling some larger projects the parts have been manufactured traditionally die casting and moulding. IDEA HUOLTO has produced highest profits of Lasi & Idea Oy, but continuous improvements are to be made to capitalize in potential of the maintenance sector that is predicted to have highly increasing number of maintenance needs and competitors.

1.7 Project risk management

It is sometimes complained that agile does not focus enough in risk management. The simple sprint structure of agile where ongoing task limitation gives the team using agile enough time to focus on sprint planning. (Brechner, 2015.) This is sometimes seen enough to mitigate risks. However stronger approach for proactive risk management should be implemented. (Satheesh, 2013.)

In this study, a simple risk registry (table 2) is used. It reveals the sprint, risk description, estimated probability, size of lost work days if occurred and the exposure. Exposure is calculated by multiplying probability against size of loss. New risks are evaluated and updated into the registry when encountered. The exposure relation to iteration is visualized as a Risk Burn-down chart. This allows fast recognition of which sprint has a high exposure to risk(s). The ideal, linear burn-down of exposure is shown as orange dotted line. (Satheesh, 2013.)

Current exposure status reveals sprint 5 as slightly above ideal linear dot line. It is now wise to focus extra effort into the mitigation process of the risk(s) before sprint 5 is started.

Table 2. Risk census

Sprint	Risk description	Propability	Size of Loss	Exposure
1	Thesis plan not suitable for project	20%	238	47.6
2	Selected theories bad or too complicated	20%	188	37.6
3	Visualization corrupted	12%	147	17.64
4	Standardization task too broad	37%	14	5.18
5	Too much data to be analysed	50%	15	7.5

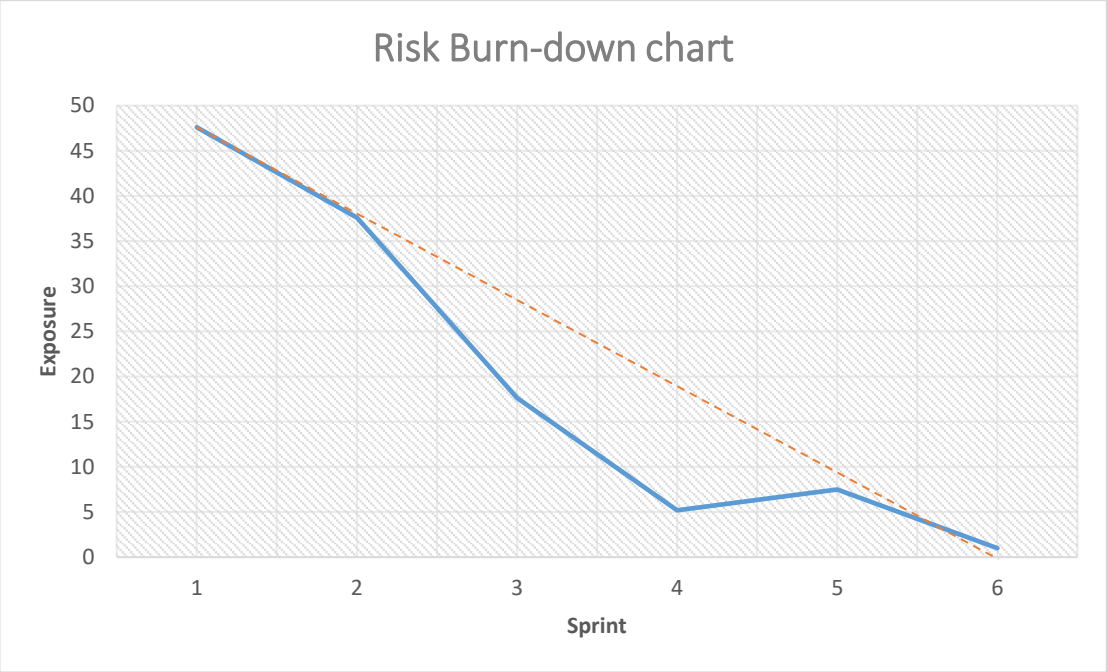


Figure 2. Risk Burn-down chart

2 Project Blueprints: Base made of Lean

“The researcher’s choice of a theory provides structure to the entire dissertation. It provides a common world view or lens from which to support one’s thinking on the problem and analysis of data” (Grant & Osanloo, 2014).

Coming from technical background, 15 years of career in construction projects, the author finds it easy to describe the theoretical framework of the thesis as blueprints of a machine. A machine that is fed materials from the supply chain, inputs, creating standardized output, while measuring the quality of the procedure.

Almost all machines however, need control to deliver orders. They need a system to oil and maintain the machine while running. In this machine it is the Project Management. A combination of Agile and Lean it focuses to finish sprints (PT) in time.

The machine that in this case is controlled by the author, is fed with right ingredients (theories) building the base for the project (PT2). The Toyota way or Lean is the foundation

and the ideology that the machine is built on. It is the perspective to build the efficiency philosophy into the theoretical framework and therefore it is the most central theory leading to the project objective (PO).

As the thesis proceeds, the next step defines and discusses the research methods, background data and any pre-assumptions or wishes towards analytics (PT3). The chosen data is analysed and suggestions respectively (PT4).

Conclusion (PT5) discusses the successfulness of the study and compiles the suggestions for fast reviewing. The product (PO) is also briefly discussed.

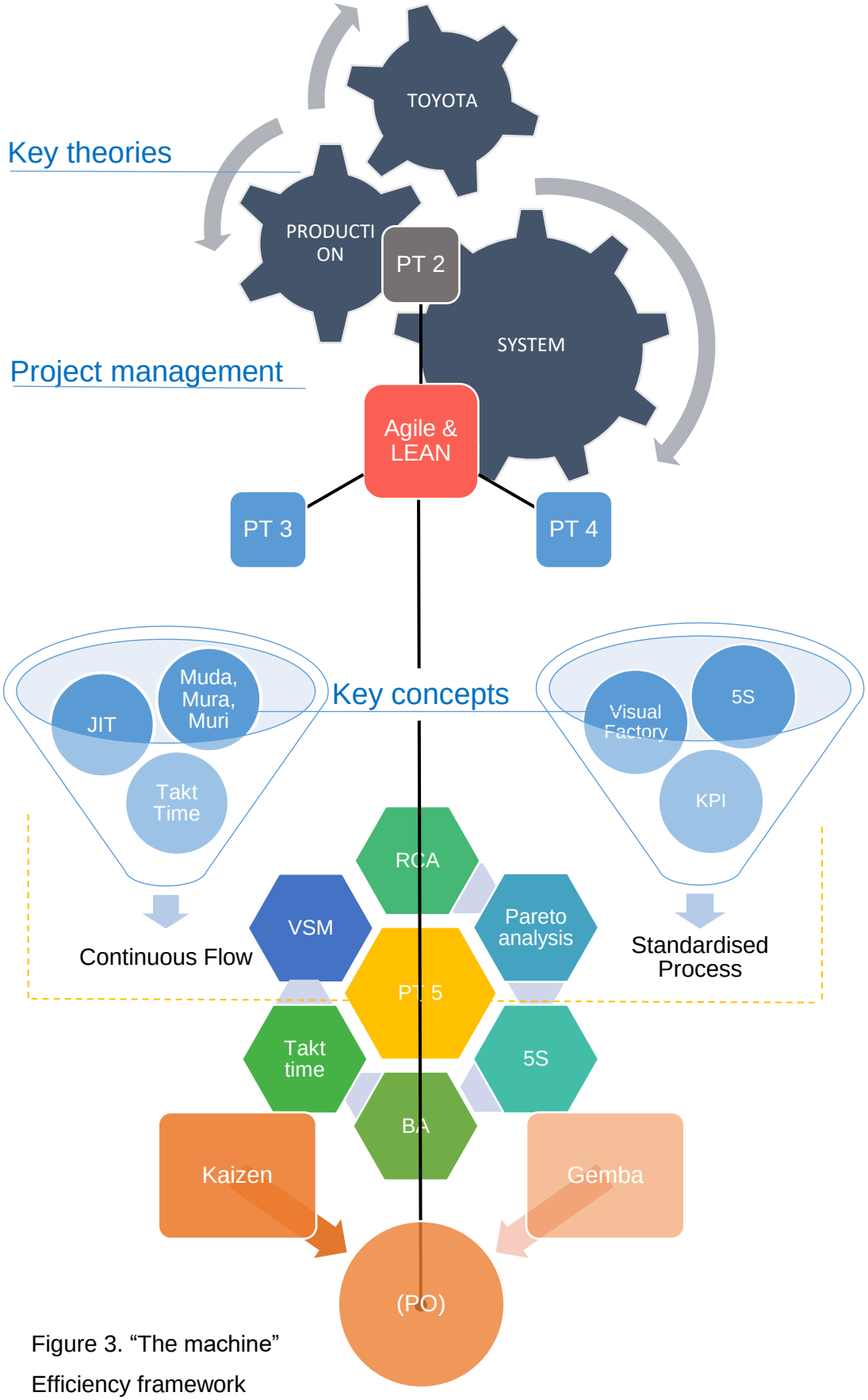


Figure 3. “The machine”

Efficiency framework

2.1 Logistics

The idea of logistics is not only about sourcing and purchasing materials from supplier to deliver them to a customer. It also includes many internal operations, hidden from the customer, who is receiving the service. The upstream network may consist of many companies, delivering the material forward and adding value each by assembling components, or for example testing assembled products. Downstream, as well, could contain several separate phases before the product reaches the hands of an end user. These levels are called tiers.

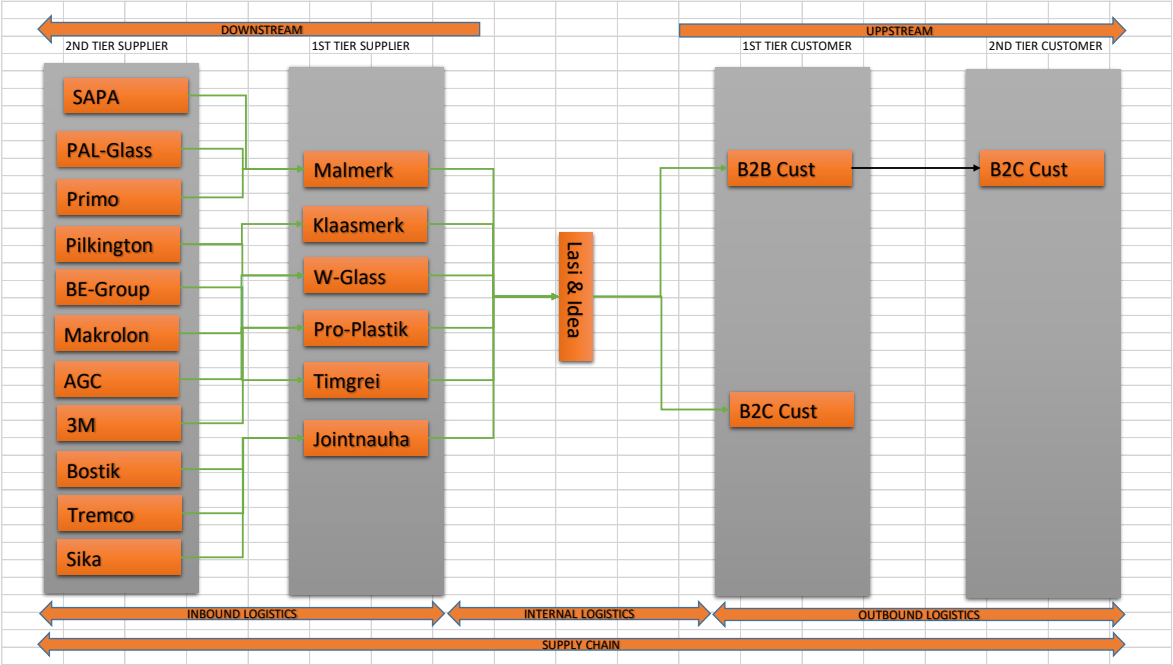


Figure 4. 2016 Lasi & Idea high-level supply chain

Goldsby and Martichenko (2005, p.4) states that besides the above mentioned, it is not accurate to define above mentioned as logistics, without the management of inventory. “If there is no inventory to move around, there is no need for logistics”.

2.2 Lean

In history of production there are early traces of process thinking from the 1450’s. A Venice located arsenal had introduced demanding process thinking in its manufacturing. However, it took hundreds of years until Henry Ford united interchangeable parts, standard work and a moving production line, into one whole manufacturing process. He called his masterpiece a flow production. Fords system used special made machines with standard quality components that fit perfectly in the assembly stage. This was revolutionary in USA,

year 1913. That time the traditional manufacturing produced general parts, which took lot of time fitting in the assembly phase. (Lean.org.)

“The problem of Ford´s system was not the flow. He was able to turn the inventories of the entire company every few days” (Lean.org). When the world demanded variety and choice, the challenge became difficult for Ford, which had produced the one type of famous T-Model 19 years unchanged. The market demand pushed the automotive industry towards more complex, slower flow production shops. Inventories and production machines grew bigger, throughput times got longer and managing the growing lag between different process steps needed more sophisticated, computerized management systems. (Lean.org.)

After 2nd world war Japan had suffered heavy losses. It´s industry and economy were struggling. In that environment Japanese industry was open for new ideology, which could improve efficiency. Kiichiro Toyoda and Taiichi Ohno in front presented simple innovations that could tackle the problems of automotive industry. The lost flow and continuity was researched, going back into the roots of Ford´s system. The new Toyota system could overcome the problems of variety by altering the process sequence. Introducing quick set-ups, acquiring self-monitoring, high quality and right sized machines that could produce needed quantities of parts. Pull design signals were also introduced to notify the previous step of the material need. The system did not only improve throughput time, but information management became simple and accurate. Toyota production lines could manufacture low cost, high quality and high variety. Toyota Production System could overcome the problems faced by the automotive industry at remarkably ambitious standards.

After 15 years of learning from Toyota developers and the the Toyota Production System, the first American president Gary Convis was introduced to run the biggest manufacturing plant of Toyota outside Japan. Gary described the need to put the people in the centre of focus. He stated that the employees should be patiently taught, rather than acquiring the most merited personnel from other companies. Gary described a set of philosophical and Management principles with technical tools that are gathered in a figure to enable continuous learning. (Liker 2004, 176.)

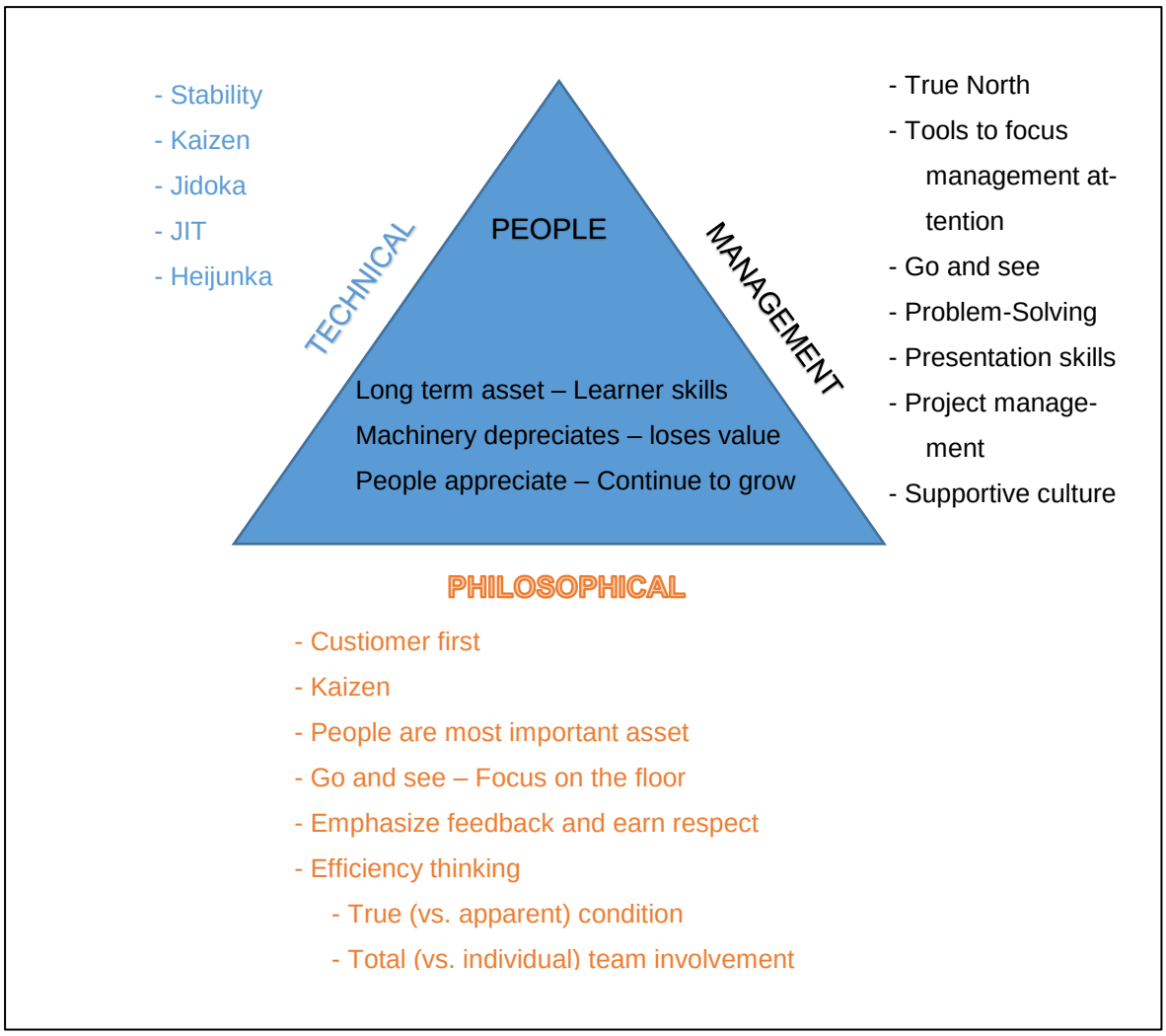


Figure 5. Toyota Production System

Toyota has implemented Lean systems in the overall management philosophy, not only in its manufacturing. According to The Toyota way (Liker 2004, 271) it is sometimes more difficult to understand process steps in a service environment, but not impossible. Once the process customer is clearly understood, a value stream map should be conducted to reveal the existing condition. It can be surprising how much waste is revealed and how the process can be standardised to be exactly repeatable.

2.2.1 Kaizen – Philosophical Hansei & Hoshin kanri

Lean is not just a toolkit for solving problems and achieving short term victories. Lean is still an ongoing learning process in Toyota. As the work must be started with a narrow scope and the problems encountered repeatedly, relentless reflection (Hansei) and continuous improvement (Kaizen) will give its practisers new possibilities to improve as an individual and, collectively as a team.

Hansei is challenging philosophical method to reflect individual from the mistakes he or she makes. It is rooted to the Japanese culture from early on. Already as a child, when doing wrong, one might get told to reflect themselves of why they behaved badly and to improve and make sure it will not happen again. The Hansei method can be used as a development meeting why something unwanted happened, or simply by reflecting a well-considered individual reflection if something failed. The meaning of this philosophical method is after all, quite practical; to understand weaknesses and learn to develop. Hansei is essential from individual's perspective to support organisations Kaizen, continuous learning. (Liker 2004, 262.)

Hoshi Kanri links together with kaizen and Hansei. It is a cascading policy deployment of Toyota. The high management sets measurable clear goals suitable to the next level. From there the goals are rendered into more detailed goals with performance indicators. The success of achieving goals is measured throughout the organisation from bottom to the top. This can be understood similarly as a strategic scorecard showing the company vision, goals and strategy. Hoshi Kanri follows the PDCA learning cycle process, where each level plays its part in Hoshi kanri. (Liker 2004, 262.)

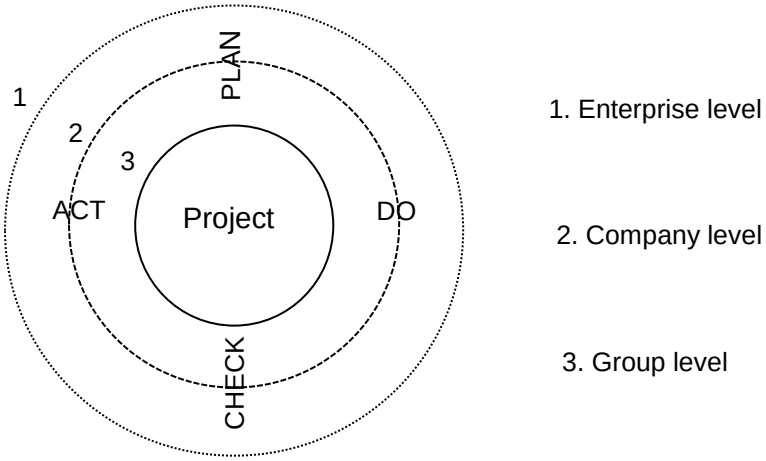


Figure 6. Deming cycle from enterprise to group level

It can seem very hierarchical, which it is to some extent. However, management is not far away, they are often in the Gemba. According to Gemba (which means the place in Japanese), management should always be as close to where the work is done. Gemba walks are made often to support the metrics by making perceptions. These perceptions are often emphasized by visual factory. Together with the strategic Hoshi Kanri and Hanshei meetings it is possible to react rapidly and to manage continuous learning.

2.2.2 The journey starts from the top

Successful Lean implementation needs leadership, education, passion and planning of change. Often introduction of new is encountered by strong change resistance. This is something that needs to be understood, as it applies to Lean as any other change in any organisations. It is human nature and extremely hard to teach away.

Lasi & Idea have started its Lean journey in 2016. Lasi & Idea is thankful of the Lean workshops provided by the consultancy company Lean 5, especially Timo Haapsaari, who is now at the service of KaVoKerr Oy, which is part of Danaher.

2.2.3 Understanding a Lean process

What is a process? As the word process originates from Latin word ‘processus’. Process is a phenomenon of ongoing elements, something being moved forward. These forward moving things are called flow units. There are many different type of processes. They are encountered daily in different operations, for example in service processes, production processes, development processes, evaluation processes, and so on. In this sub-chapter it is important to understand what is a process and what are the differences between a process, built around a resource or, a flow unit. (Modig & Åhlström 2013, 19.)

The process often needs to be exploded into its elements to fully understand how the processes develops from start to finish, as in flow of units. These flow units can be made of people; a person going to the dentist to have teeth whitened, going through different activities between arrivals and checking out. A flow unit can also be a broken balcony glass, part of glazing system that go through separate maintenance phases between dismounting and re-installation. It is also possible that a flow unit is intangible information. It can be an application to city building department, going through separate phases before person is given, or denied a permission to build. (Modig & Åhlström 2013, 19.)

2.2.4 Resource vs flow, push vs pull

Jeffrey K. Liker (2004, 90) was welcomed unrestricted access to Toyota Production System in Japan and USA. He found out that producing in one-piece flow was not the only way of Toyota. Buffer inventories were used where necessary and mass production thinking where one-piece flow was not possible.

Resource efficiency is typically seen in mass production. The processes are often chopped in small units of similar people and machines. This allows easier management of the same people using same machines, specified only for tasks received by the unit. Characteristics of mass production thinking are:

- Unit receives tasks in large batches
- Able to produce very high numbers in short amount of time
- Economies of scale
- Simple individual scheduling of each unit
- Low costs of resource use
- High unit efficiency
- Pushing information and material to the next designed unit

Typically, separate small units with each unit dealing with their own process, have several supportive needs. The unit is often unable to control itself as it consists of only similar skill and machinery. This creates a need for other units with their own special tasks. Finished goods of large batches, completed by different units, are pushed forwards to the next unit. This creates yet another need, large unit inventories and large work-in-progress (WIP) inventories that creates units managing them. (Liker 2004, 101.)

Large, fast, cost efficient machines do not produce small numbers cost efficiently, therefore the batches end up waiting for the right moment to be pushed further to the next unit. From Lean perspective, this creates enormous amounts of waste between the units.

The batch production with its near supporting units is described in batch production design (figure 9). Stock management communicates with the stock, stock gets replenishments according management schedule. It is often seen that the stock inventory is an enormous logistics hub that serves the production. These logistic hubs tend to be located outside large cities, next to good infrastructure. Sometimes transportation distances become long between manufacturing and inventory.

Assembly management communicates with the assembly, schedules the production and makes sure the resources needed are there to finish the designed process. The Blue block arrow shows the flow of the material from stock to assembly.

After assembly material is moved to the work-in-process inventory according schedule made by the WIP inventory management. Material is again pushed to the next process form the WIP by the inventory management, who communicates with WIP inventory and the assembly units. These are the near units, but if taken a larger scope, there are pur-

chasing departments, human resource departments, R&D departments etc. These separate units follow a complex design of communicating together. In large companies sophisticated Enterprise Resource Planning (ERP) is needed to integrate all these units, but still it is common to see a delay when, material or information reach a new unit. The dashed lines represent information flow and the solid arrows are material flow.

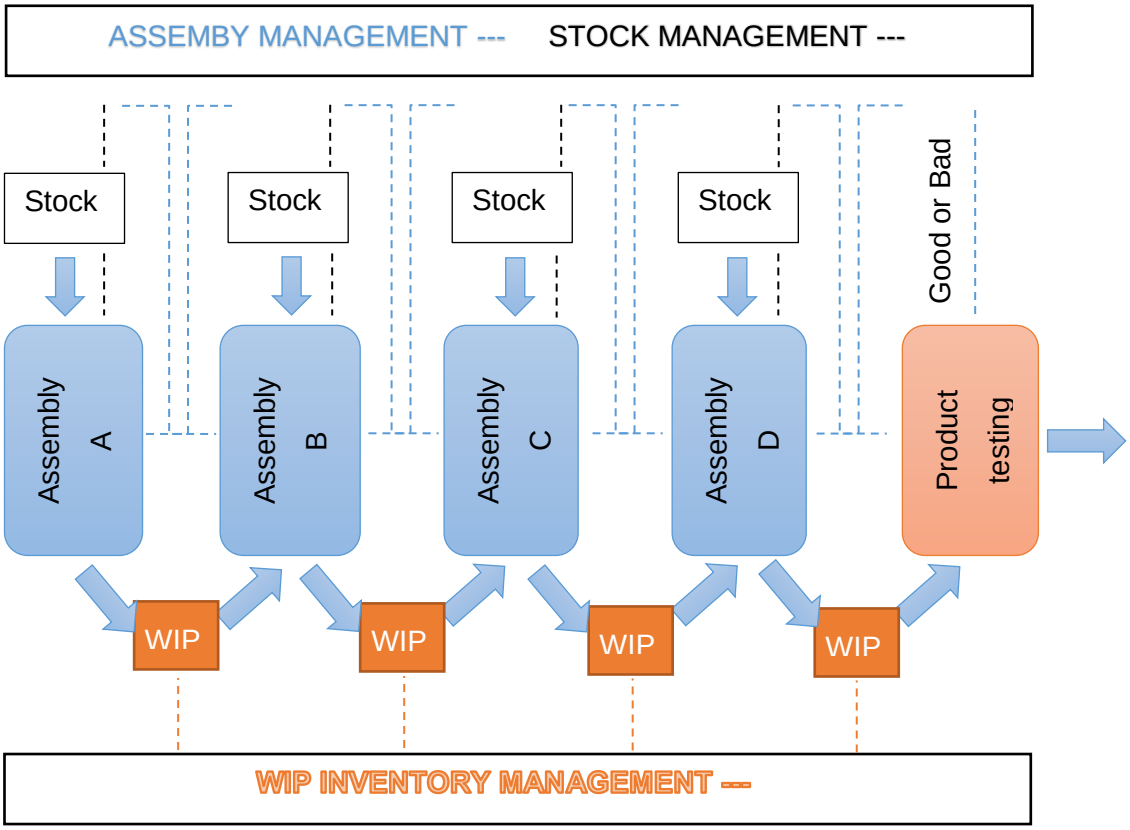


Figure 9. Batch production design

When the process boundaries are set to what is visible from material arriving to Assembly A to completion of product testing in figure 9, it is possible to measure time from the first step of the process to completion. This is called lead time. It is a common performance indicator used measuring overall process speed. Focusing on the assembly A, only using lead time could be possible, but it is easy to miss indirect hidden tasks, for example cleaning or maintaining the assembly line. Therefore, it is better to use cycle time, time measured from Arrival of Batch A to Arrival of Batch B. (Liker 2004, 101.)

Earlier in this sub chapter a list of positive characteristics of resource efficiency was presented. It is also important to list the key challenges created by this thinking. Jeffrey K, Liker (2004, 91) describes several challenges from flow perspective:

- Overproduction

- Need for large inventories
- Separate units and processes cause delay in receiving and sending value
- High number of sub-assemblies
- Large, rapidly handled processes create defects as fast as good products

The process can be built the other way around. Going to see a doctor would mean that the customer would act as a flow unit. In this case the flow unit determines the need. The process is built to maximize value receiving time to the flow unit (Modig & Åhlström 2013, 22). Describing the process from the flow unit perspective allows a mind-set of how the customer, whether internal or external, receive the maximum value during process lead time.

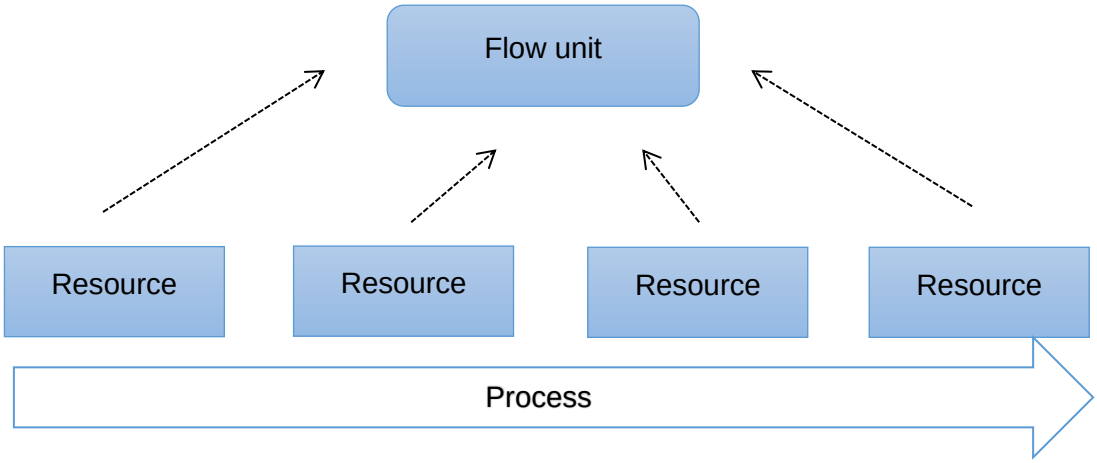


Figure 10. Flow efficiency

“The system that Ohno set up does not assume that ideal batch size is what is most efficient for each individual process or for the material handling department. In Lean thinking, the ideal batch size is always the same---one” (Liker 2004, 92).

By assigning the separate units, as close as it is possible, to a one cell and downsizing the batch to one product, the complexity of the design can be eliminated. Integrating assembly management, stock management, WIP Inventory management into a one cell assembly the process looks totally different.

The large inventories are no longer needed, the need for the management decreases as well as it moves closer to the actual production. This creates need for different inventory replenishment, a pull system able to deliver Just-in-time replenishments as well as a management and communication channel called Kanban. JIT purchasing, and Kanban are discussed more intensively under their corresponding titles.

In figure 11 JIT-stock serves to replenish calculated demand of assembly, Inventory Management an IM and WIP Inventory Management is not needed as there will be no Work-In-Process inventory to manage. Instead between the assemblies First-In-First-Out lanes must be built. It is a transportation lane where first product that comes in goes out. Simply this means that maximum Work-In-Process inventory should be two, where minimum is zero. When small assembly floor inventory is kept there is need for small rapid inventory that delivers frequently. The Cyan arrows represent the flow of units, where the black dash lines describe need based Kanban tickets pulling necessary inventory or telling the previous step to send a flow unit forward.

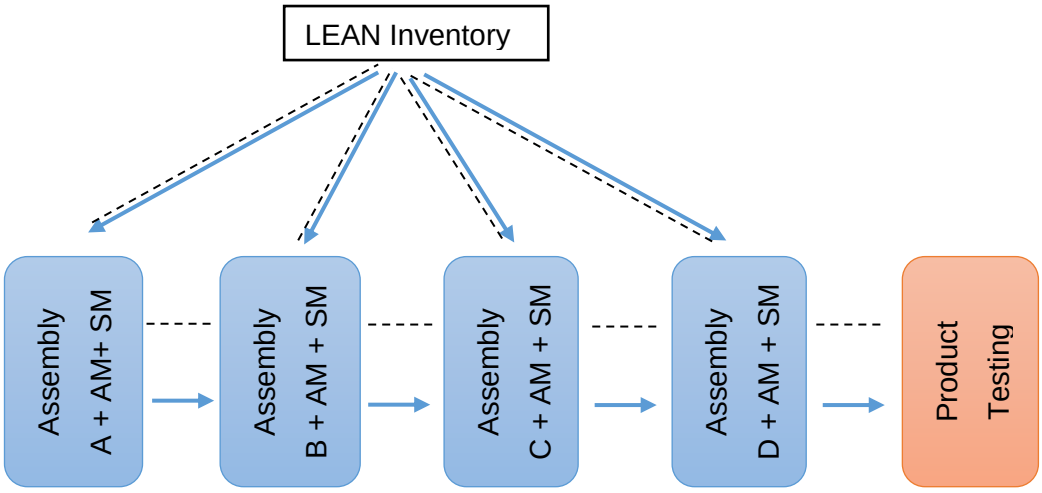


Figure 11. Lean one cell pull design.

Why should pull based flow value chain be created? What are the benefits? Simply reducing the unit number being processed to one, unit that is always pulled from the previous step, creates a system that does not overproduce and makes large inventories unnecessary (Liker 2004, 93).

Quality is improved by detecting defects much faster. Let's go back to a resource efficient model again. If the resource efficient assembly model ideal production batch would be 10 000 units that would mean that 60 000 units between assembly A and productions testing could have defected component from assembly A. With the flow production system only six units between assembly A might have defected component attached. (Liker 2004, 93.)

Flexibility is also highly improved. If the demand of the customer changes the situation is in flow production is much better, there was no overproduction. Also, the first complete product is out from the production line much faster vs resource efficient conveyor. Cost of inventory is highly reduced. This frees up capital to be invested into something else. Along

with the organisational benefits, also individual benefits have been studied in Toyota. (Liker 2004, 95.)

- Increase of productivity through more value-added work
- Improves safety through decreasing heavy machinery
- Improves morale as results of work are visible earlier

The design itself does not guarantee flow and it needs tools to create it. Taiichi Ohno, states that, building a flow efficient system needs patience and the system needs continuous improvements and monitoring to bring results (Liker 2004, 98). While the inventory, or large batch size is no longer hiding problems and low efficiency, it is possible to start fixing the problems that are found (Liker 2004, 99). The flow enabling tools will be discussed in the next chapter.

2.2.5 Muda, Mura, Muri

The basic, simplified idea of Lean is to increase speed and flow (Goldsby & Martichenko 2005, 4). Improvements are not conducted by running faster or acquiring faster machines, instead it is about understanding and analysing the process and becoming clean of anything excess.

It is fair to say that all professional activity costs time and is paid by a customer to receive the value. If a company succeeds to sell a customer much non-value adding activity, would it be better to allocate resources to do something that would bring more value to the customer? The non-value adding activity in Japanese is called Muda or more commonly to the western world- waste. Minimising Muda and maximising customer value is what Lean, in its simplest, is about (Lean.org).

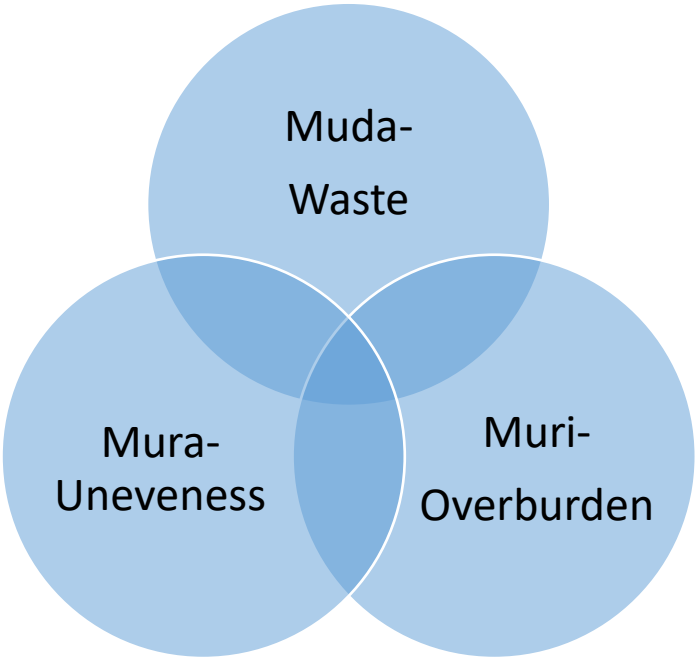


Figure 7. Three connected M´s of Lean

Taiichi Ohno, the author of Toyota Production System (TPS) listed seven wastes in manufacturing according to LeanCor (LeanCor.org). Goldsby and Martichenko (2005, p.4) have enhanced the original seven wastes to fit to logistics. The glued glazing maintenance has production steps as well as logistics steps. Understanding and categorizing the wastes is important. In the Value Stream map (PO) each activity is categorized by the waste and whether it adds value or not.

Table 3. Different waste for different process

TPS "original" 7 wastes	**Goldsby & Martichenko logistics waste**
1.Overproduction	1.Excess inventory
2.Waiting	2.Transportation
3.Unecessary transport or conveyance	3.Space and facilities
4.Overprocessing or incorrect processing	4.Time
5. Excess inventory	5.Packaging
6.Unnecessary movement	6.Administration
7.Defects	7.Knowledge

The seven Toyota waste can be also found from the book The Toyota Way (Liker 2004, 28) and the original 7 wastes are chosen for the Value Stream map. However, the logistics wastes can help to understand especially the parts, where packing and transportation is conducted. If a straightforward way to mark the logistics wastes are found, they can be added as a secondary signal.

Most of the times, the Lean projects concentrate on removing Muda. It is understandable as it results from activity and are amongst the first visible things in Lean consultants list. A sorted work floor and a Muda-free process of one-unit flow will work if the demand stays the same. The problems start arising when the need for different type of variations and changing demand step into to the picture causing people and machines to work over their limits, therefore becoming overburdened. If focus is only on Muda it is possible to cause even bigger problems as people and eventually the entire system becomes unstable and less productive. Eliminating Muda, muri and Mura are as important and must be used together. (Liker 2004, 115.)

Jeffrey K. Liker (Liker 2004, 114) describes the 3M characteristics as follows:

Muda – The 8 wastes: overproduction, waiting, unnecessary transport, over processing, excess inventory, unnecessary movement, defects, unused employee creativity. They are created by unnecessary inventories, extra walks of fetching needed items and waiting. They all end up stretching lead time, increasing system bound money.

Muri – Sets a speed limit to the process, like a speed by the road, assuring safe and controlled driving. Without it people and machines get overloaded. This overburden lowers quality and may damage machines and harm people.

Mura – Changes in schedule and production quantity causing unevenness, often caused by lack of muri. Mura is also seen to cause Muda; for example, work-in-process inventories. Unevenness requires much supporting resources in controlling a system.

2.2.6 Balance with Heijunka

Taiichi Ohno states that it is better to keep moving slowly at a steady predictable pace than doing highs speed sprints like a cheetah running fast and stopping to regain its energy. This running and stopping causes lots of waste. (Liker 2004, 114.)

Creating the leanest possible waste less one-unit flow in a certain process could seem like the most desirable option, but it is not that easy. The process that answers simply to customer demand will cause a lot of overburden for workers and machinery when customers place unexpected high-volume orders. It will become even more difficult when the process has various products put through. This overburden is quick to change to unevenness, when there is less than average amount of orders. (Liker 2004, 116.)

The unevenness caused by this one process schedule speeding up and slowing down becomes even more visible when analysing the whole value chain. It creates a need for other processes to swing accordingly, creating unplanned inventories and pushing the system to handle batches of flow units. The unevenness spreads to the entire system, making JIT delivery impossible. The further upstream inspected, the more serious uneven demand is caused by the swinging process. This is called a “bullwhip effect” and it forces the suppliers to set up massive inventories to be able to deliver unpredictable shipments according to changing demands. (Liker 2004, 118.)

Heijunka sets limits to the flow that the entire system can be balanced steady and under control. Achieving Heijunka needs planning of the schedule much forehand according to planned process throughput time. Sometimes it is needed to create necessary waste in form of finished goods inventories between processes to allow steady scheduling. Planning of workload for workers is also part of Heijunka, this can be for example not scheduling two work intensive product manufacturing in a row, but instead doing a schedule of medium, heavy, easy tasks to avoid overburdening workers.

2.3 Creating continuous flow

It is not easy to create a continuous flow. Creating a flow in a small isolated process could be easy in theory. Implementing it from theory requires a large knowledge base of how to create a true one-unit flow.

Creating a flow is only half of the needed ingredients. The other half can be even more challenging, keeping it stable and running. This chapter discusses of the flow and the major supporting theories how to maintain it.

2.3.1 JIT

Just in Time or JIT purchasing system aims to reduce materials and work-in-progress inventories by adjusting production capacity and assembly to match the actual demand. Pioneer in defining JIT was Lee White as “an inventory control philosophy whose goal is to maintain just enough material in just the right place at just the right time to make just the right amount of product” (Lysons 2000, 248.)

Several versions of just in time systems exists, like ZIPS, MAN, DOPS and NOT. They all share same common characteristics in providing small quantities in high frequency originating from TPS Kanban.

Integral part of the Toyota Production System is how each process steps communicate of their needs in quantity and quality. The ticket created between the process steps forms an information system called Kanban. The system respects the pull method, retrieving information from the last process steps towards the beginning of a process. When correctly conducted, the previous step is always aware of what kind of quantity and quality is needed to the next step." (Lysons 2000, 248.)

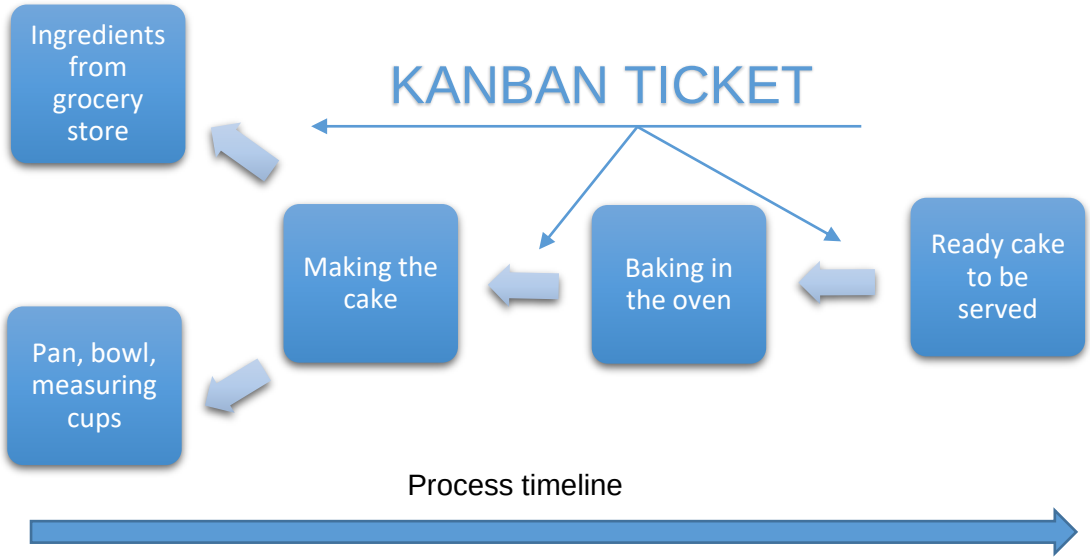


Figure 8. Kanban ticket in baking.

To function, users of JIT system must first understand that unorganized JIT easily become 'just-too-late'. It will seriously harm the flow of units as it can stop the entire process. It is reasonable to say that without deliveries to intended destination, at predetermined time, quality and quantity, JIT does not add desired value. (Lysons 2000, 248.)

Other challenges that should be highlighted and can cause serious problems, is misunderstanding that by using JIT, it is possible to operate without inventory. If so, it is very likely that shortages will stop the process. Safety stocks should not be overlooked, either. It is also likely that purchasing small quantities frequently, the supplier might feel the need for higher prices compared to large single purchases. (Lysons 2000, 250.)

Lysons (2000, 249) states key focus points how to succeed in JIT. First, for a buyer to achieve a relationship with a supplier that serves the purposes of long term, dependable partnership, strong mutual effort is needed. Both parties must commit to a system, which does not leave much room for error. It is also beneficial if the supplier is located as near as possible. Shorter routes give faster lead times and lower the risk of transportation issues. Besides the mutually planned standardized system a trustworthy relationship with the supplier means freedom in how they can achieve the results desired; JIT should not become a burden for the supplier.

Adopting JIT purchasing system has been studied by Ansari & Schonenberger in 1988 and 1990. According to their studies companies that adopted JIT purchasing estimated product quality increase of 43 percent and productivity increase of 21 percent. (Kaynak & Bimmerle 1996, 19.)

The frequency of monthly ordering increased from 2.8 to 6.9, states O'Neal in his studies, year 1987. Other similar findings made by Dion et al in 1992 found JIT to increase deliveries 200%, while shortening order lead times 50%, with 50% smaller order sizes. (Kaynak 1997, 72.)

2.3.2 TAKT time – setting speed for the flow to avoid bottle necks

A conductor signalling the beat for the orchestra and the drummer for the rock band leading others for the beat. What do these have in common with continuous flow? When the drummer hits the beat, the rest of the band plays the instruments by the tempo set. The sounds from the instruments with the same beat become music. This is same what takt time does for the flow, it creates a rhythm.

Takt time can be used certain ways. One way is that speed of production is based on the customer demand of units produced. It can also be used as a tool after a singling out the slowest bottle neck of the process steps to set the pace for the other steps. If other steps are faster bottleneck gathers an inventory in front of it, so in other words earlier process steps are overproducing.

2.3.3 Value stream mapping

Understanding current condition of the process should be amongst the first things on the journey to create efficient flow. VSM – Value stream mapping is an excellent tool for this

purpose. By visualizing the process, waste can be revealed, opportunities found and learning towards improvements may begin. As process steps are all individual for different operations, it is important not to duplicate solutions that worked in other operations. It might give some help, but it will not reveal all the potential. Not to even mention about the beginning of continuous learning, a topic which will be later discussed more closely. (Carreira & Trudell 2006, 65.)

2.4 Standardised process

It is important to understand what standardisation means. It should be thought as a fixed way of doing something with fixed accessories. Let us assume a situation where one with little experience is starting to bake. The recipe of a delicious cake tells us to have a suitable mixing bowl and a pan. Ingredients 1 cup of white sugar, 1 ½ cup of butter, 2 eggs, 2 teaspoons of vanilla extract 1 ½ cups of all-purpose flour, 1 ¾ teaspoons baking powder and half a cup of milk. There is a certain order of mixing the ingredients, time 30-40 min and temperature of 175 baking to achieve a goal; a cake that tastes and looks good. Now is there a standardised work plan of doing it, something that could be repeated? No, not really. At what time the oven is put on, what is a good-looking cake and what does it taste like? Where can one get the accessories or the ingredients?

According to Goldsby and Martichenko (2005, p.233), it is essential to understand standards as only through standards one can understand what is happening with the process now and how it can be improved the next time. Besides a standardised work plan, there must be clear and expectable inputs, procedure and outputs. When they are well documented, it should allow someone with even little previous experience to succeed in the operation and become excellent in brief time.

Baking with a vague recipe could have a considerable risk of complete failure. Even though there probably is a steep learning curve by learning from mistakes, it is very likely that after making 5 of these cakes, not all are the same. By standardising the recipe, it is possible to start understanding why the cakes are not the same.

2.4.1 5S

Often experiencing a feeling that something is missing, whether it’s a tangible tool or information, it is not where it should be? Looking for the missing things is not adding value for

the customer. Thinking again the receipt for the customer that holds all the activity completed, it is possible that 10% of total activity was looking for something that was needed for the work. It would not be something that the customer is happy to pay for. It is simply taking time and money.

5S stands for Seiri, Seiton, Seiso, Seiketsu and Shitsuke. 5S is a method of organizing a workplace and maintaining it. It is supporting the continuous flow by standardising what is really needed, where and what quantity. 5S has been translated into English and the 5S´s stands as Sort, Straighten, Shine, Standardise and Sustain. (Liker 2004, 150.)

An effective execution of a task needs tools that are in predetermined place, as near as possible and in a way that it is clear and safe to use them. 5S is applicable for improving efficiency in production as well as in an office. It is often introduced as a quick results method of Lean and misunderstood to give all benefits of it. This assumption is wrong, it should be a small part of a company's Lean journey. (Liker 2004, 151.)

Timo Haapsaari (Lean 5) states that lack of organisation and standardisation is causing 80% of the quantity of process problems faced, despite the seemingly clear visibility of these problems. This could be that even though items are sorted out neatly, there is no system to describe the item´s place clearly enough or the unneeded things make it difficult to find needed items. Sometimes the items do have their place and the workplace is cleaned thoroughly enough to eat from the floor, but the incentives are missing, so there is simply no time available for the sorting and cleaning. Sometimes it is the case that a new system is adopted and run perfectly for a while, but as it is not inspected things go back to their old ways.

5S cycle implementation is often one of the first things implemented. It should begin with sorting the workshop, leaving only the necessary material for each workstation. Standardised working guidelines should be brought into every workstation. Straightening uses visual factory by signalling movement paths to from workstation to another. Straightening tools in the order they will be used can be a clever idea. Shine can be determined by the reference overall cleanliness. Creating rules that makes sure the system is used is necessary along with audits to review and measure the success of the system. (Cudney, Furterer & Dietrich 2014, 420)

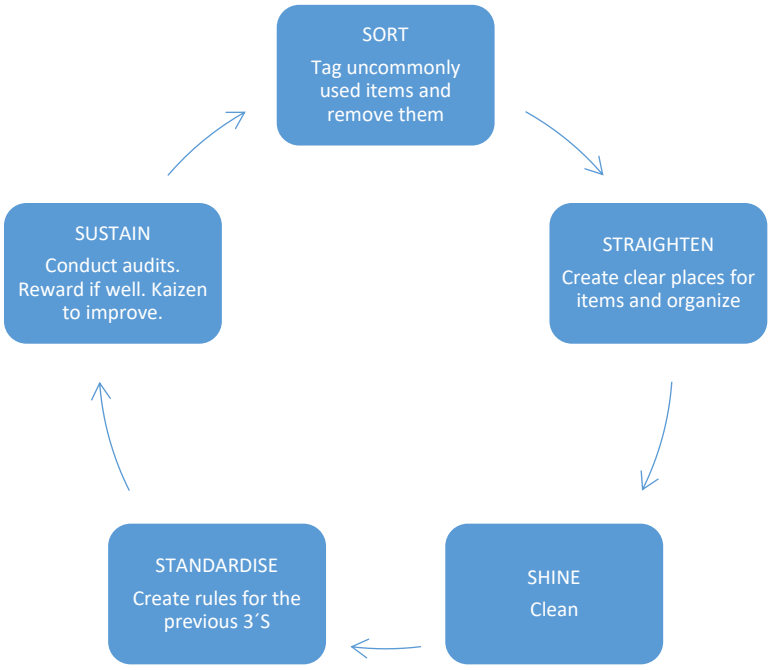


Figure 9. 5S cycle.

When continuous flow is desired it is impossible to sustain it, if the operator does not find items needed for the task. 5S also helps its pedant user to remove waste and make the process repeatable. It is important to integrate 5S into the takt time of the process, this way it will be conducted as scheduled.

2.4.2 Visual factory

Humans are oriented to experience surroundings by touching, seeing and listening (Liker 2004, 158). According to Toyota, “well developed visual control system increases productivity, reduces defects and mistakes, helps meet deadlines, facilitates communication, improves safety, lowers costs, and generally gives the workers more control over their environment” (Liker 2004, 158).

The idea of a Visual Factory is to create visual control by sounds, light etc. to single out deviation exactly where the deviation happens and where it is important to acknowledge it. In an execution level, shadow tools can be drawn to a wall to inform a worker that here is the place for the wrench. It is also possible to use visual factory to inform a quantity of how many wrenches the desired work floor inventory should have to ensure flow. If something is missing a manager can consult his or her everyday-Gemba-walks and notice immediately if something is not according to the planned standard. (Liker 2004, 158.)

Timo Haapsaari (Lean 5) explained a case where a manufacturer's maintenance crew had a large mix boxes of tools on top of each other, taking so much space from the storage room that it was difficult to get to the shelves where inventory was located. These buffer inventories were not created according to a plan, but the tools were the ones which had been lost and found again later. This caused waste in looking for the tools, moving the overburdened storage room boxes to find needed things. This led the maintenance crew constantly doing much non-value adding activities. Also, company was forced to use resources and money to order new tools that eventually would end up in large excess mix tool boxes. As a solution the inventory was sorted out of extra tools and a shadow tool board was created to indicate place and quantity for each item necessary.

Despite creating a place for every item, the tools still sometimes ended up being lost. The problem was analysed with the maintenance crew using a root cause method, formulating more and more in-depth questions why the tools still ended up missing. The result was that as no one could know who lost the tool, losing the tool was just a lost tool by the crew. The solution was to give each worker a colour, the vests held a place of a colour tag of a worker that was left to the pin if a tool was borrowed from a shadow board. Therefore, everyone was aware who had it and whether it was in use or lost. Problem solved.

2.4.3 KPI

Lasi & Idea have no predetermined process efficiency related key performance indicators. To be able to achieve progress they must be adopted. KPI´s are also important on the control stages of the process. As the company have no earlier Lean projects to this extent the focus is to conduct as detailed possible Value Stream map. Where both qualitative or quantitative data can be retrieved. Author is familiar for selecting KPI´s previously. There should be only few performance indicators at the beginning. Ideally 3-4, what is expected beforehand are based on the suggestions of Lean systems (Cudney, Furterer & Dietrich 2014, 310). It is likely that process lead time will be used as overall performance indicator of executing the entire process.

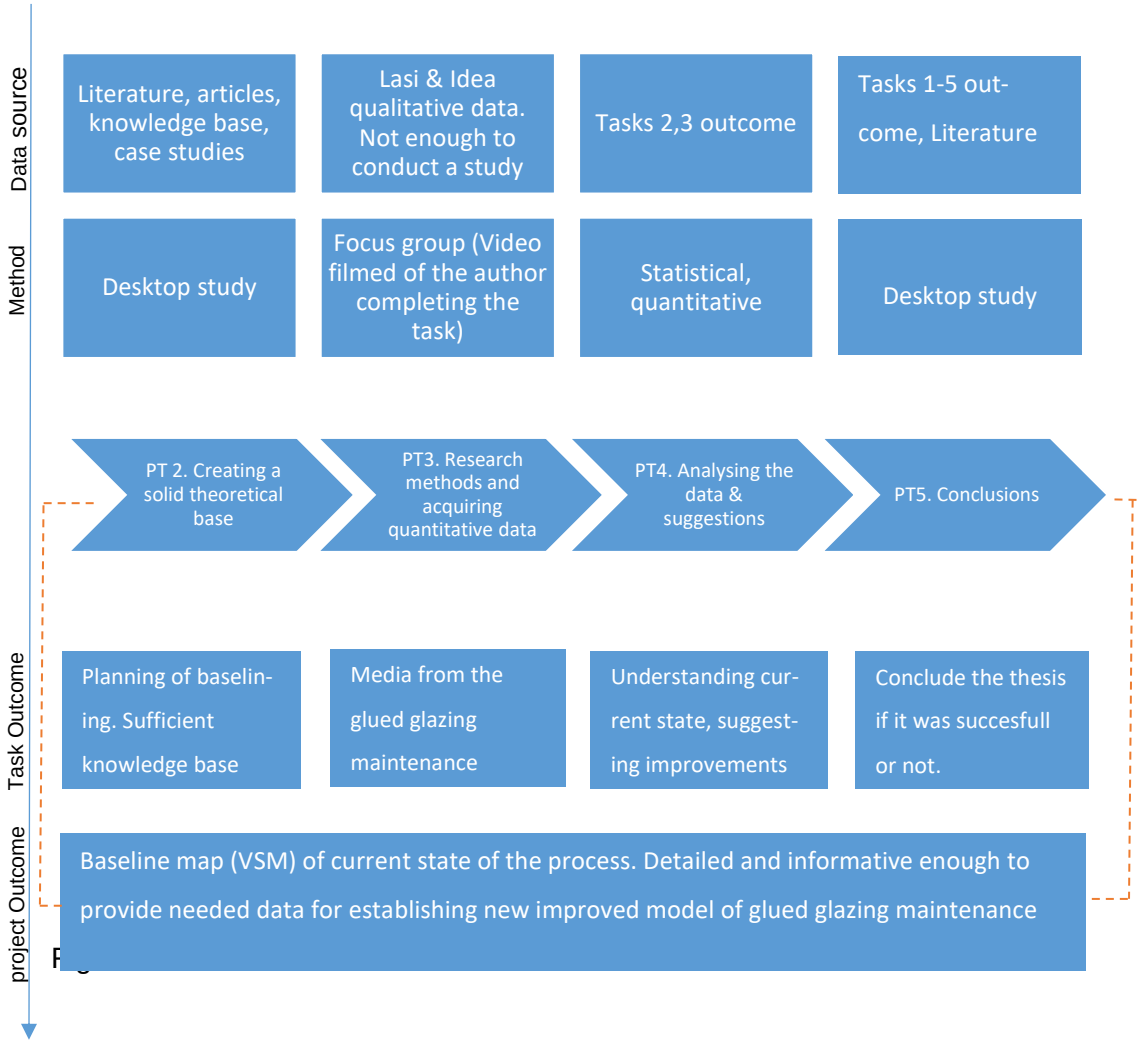
- Takt time of process steps
- Value adding time %
- Lead time or cycle time

3 Methods to manage and research

Wrong research methods can produce false assumptions as likely as bad project management can lead to a situation where the whole project fails. Where the project management needs its biggest focus in the beginning and end of the process the research methods carry the author over the mid-section of this thesis. Each tasks and research methods can be seen from the research methods (figure 12).

3.1 Project management methods

Management model of this project oriented thesis is a hybrid. Leaning towards agile this model combines parts from agile, waterfall and Lean philosophy. Each task is an agile sprint and the work itself is limited into maximum 3 ongoing project tasks. This is because of project task 4 cannot start before tasks 1-3 are completed and tasks 2-5 should not be completed before task 1 is completed. Tasks have not been cut into smaller same size tasks in this stage. If necessary tasks in final steps will be divided into sub tasks that will last if the shortest single task. The timeline is continuously updated and followed how the project is developing under schedule (Brechner, 2015).



3.2 Qualitative or quantitative data

Lasi & Idea have not used Key Performance Indicators (KPI) to measure success in pre-defined repeated processes. However, customers have been encouraged to give qualita-tive feedback of the service received since 2013. The feedback has been collected, by the management board and it has been used to improve the service towards desired goals. Customer given qualitative improvement wishes, function as a base of setting the thesis goals.

In glued glazing maintenance, Lasi & Idea has most of the time two external customers. In most cases the balcony glazing is owned by the building management, but they create value for the habitant, who lives in the apartment. The mainly desired improvements are grouped under respectable customer to clarify the needs of each customer.

Resident's priority is more about strangers entering their home and spending time with their personal surroundings and items. This causes different approach with the residents. Sometimes there are no resistance to Lasi & Idea maintenance entering their premises, however they might still have uncomfortable feeling about it. Sometimes the resident does not wish to let Lasi & Idea personnel enter by themselves; the reason being a pet, children, vacation or simply uncomfortable feeling of strangers in their home. The resident´s main improvement wishes have been:

- Time
- Better Communication
- Better information who is coming, when and what is happening
- Cleanliness

The most challenging improvement wish experienced by Lasi & Idea personnel, including the author, is the communication. Selling desired level of communication to the managing board receive always the same feedback. There is always a contract with the general building maintenance, which is responsible of communication. The reality experienced is that there is no desire to communicate as extensively as there is need from the residents. The main problems considering lack information have been, incorrect information, Lack of information, Information channel is not suitable for information desired or Information did not arrive in time.

The result is that the resident has no idea what the maintenance is about, when approached. This causes more problems that Lasi & Idea is unprepared for. Entrance is not possible at time scheduled. Balcony is a storage, clearing is needed. Balcony has furniture not designed to last unprotected from rain and wind.

The board representative's focus points are costs of time and money. From costs following topics can be formed:

- Value received per € spent
- Quantity of tasks to be responded to
- Amount of third party quality inspection needed

The author did not find qualitative data to be accurate enough to conduct a study based on it. However, the qualitative data available is useful for providing assumptions, which way to lead the study.

Due to the absence of good qualitative data and the more unbiased nature of the quantitative data, the author decided focus on the quantitative data analysis (Davies & Hughes

2014, 9). However, observations were made to allow analysing of qualitative data if necessary. The task of maintaining glued glazing was chosen to be filmed with a GoPro attached to the author conducting the work. The decision of filming was influenced by the 12th Toyota way principle “Genchi genbutsu – Go and see for yourself to thoroughly understand the situation” (Liker 2004, 40).

In project tasks (PT3) three and four a video of the work itself was captured in May-June 2017. The film consists media throughout the construction site to workshop and back process starting from arriving to the customer premises and preparing the transport unit, with entering customer apartment and into the point of work completed.

The author itself has been actively involved in the projects of the company. Author’s knowledge base of the topic is large, but relying on that should be conducted under great care that the conclusion used are much objective. The data from project tasks three and four will be analysed as a task five in the next chapter.

4 Analysis of glued glazing system maintenance

This chapter focuses to analyse how the selected theories are applicable to the new acquired quantitative data from the value stream map and what is needed to achieve flow in the glued glazing system maintenance process. The next step is unveiling the current state of the process by using Value Stream Mapping.

4.1 Kaizen event vs DMAIC model

The system design is chosen to follow a Lean PDCA kaizen event over DMAIC of Lean Six Sigma. The decision to choose kaizen event was affected primarily by the simplicity, better suitability smaller processes. Whereas Lean Six Sigma DMAIC excels in larger, more biased processes, with access to large amount of quantitative data. Secondly, where DMAIC is considered an excellent model of reducing defects, the Kaizen event is also expected to give the needed results, especially with its hands-on approach. (Carreira & Trudell 2006, 18.) Lasi & Idea have arranged two kaizen events before. It is why the author also believes that the previous experience will help continuing in the same path.

The do part focuses in executing a value stream analysis, what enables both quantitative and qualitative data of the existing process condition. Value stream map is also the product of this thesis.

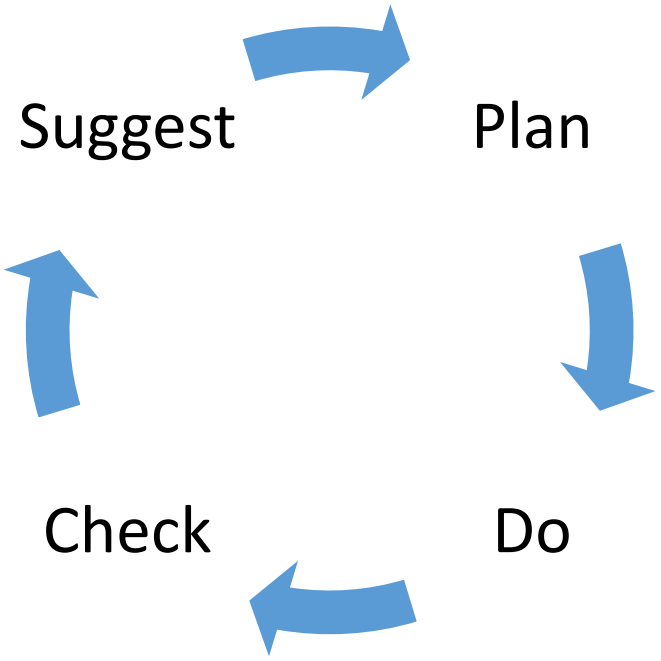


Figure 11. Thesis enhanced Plan-Do-Check-Act cycle

4.2 VSM – Value Stream Mapping

Value stream mapping was chosen to be the core tool, as well as the project objective, a product of the thesis. Firstly, the author would like to highlight the importance of value stream mapping in revealing problems in form of waste. As Jeffrey K. Liker states in chapter 3 of The Toyota Way, eliminating waste is the corner stone of Toyota Production System (Liker, 2004).

VSM was conducted by filming a video of the task starting from the front of the building and ending to the point of maintenance finished and returning to the point of origin. This was the author had an ideal approach of seeing the task himself, respecting the 12th Toyota principle. The original seven wastes of Toyota Production System were used. The seven wastes can be found from the waste matrix (appendix 2).

Conducting a value stream map is a handful, time taking and therefore it is mostly suggested to be executed by a team responsible of the task along with its management. Because of the restrictions of this thesis the VSM boundaries was narrowed to the actual hands on maintenance, leaving out administration and communication in before and after the task. Despite of narrowing down VSM it ended up giving 28 pages of activity (appendix 1), categorized in Value adding, non-value adding but needed waste and waste, each one in its respectable row of activity boxes. By doing this the primary goal was to under-

stand what activity really brings value to the customer and secondary to allow understanding what part of the waste is caused by the glued glazing design and what was simply waste and not needed. Thinking how it really brings value to the customer, while writing down activity is important. Example of this was in gluing process and especially re-installing of glasses. The customers have been very pleased of our final quality so the author, at first allocated over 68 minutes and 26 seconds of glue seam finishing and tidying it up to value adding activity. In a project where 100 balconies go through the similar glue maintenance it means over 114 hours and 27 minutes. While watching the video and counting seconds doubts started arising. Is it necessary?

Table 4. Root cause analysis value or waste

Why it adds value to the customer?
To have finished quality look and the maximum durability of the glue
Why it takes long time to achieve this?
While gluing to achieve maximum amount of glue inside the list the excess glue comes out when glass is pressed into the list
Why it is needed to have excess glue?
The shape of the pressure glue gun nozzle by SIKA does not allow exact positioning of the glue into the complex inner shape of the glass list

The root cause analysis allowed understanding, that finishing glue seams was waste caused by the defective gluing process, rather than value adding activity. The quality was not built into the gluing process, but repaired afterwards.

The next step was to determine the waste. This is more challenging as it does sound at the first. The visible waste was often caused by another waste. Root cause analysis was used several times. As an example of this appendix 1 first page black box of excess inventory was of 19 seconds of waste that did seem like waste 6. Unnecessary movement of reaching and searching for a tool which was needed non-value adding activity. The root cause was determined again by asking why until root cause was found.

Table 5. Which waste root cause analysis

Why need to step down stairs to search for a screw tip?
Need right screw tip to open panel locking screw
Why the screw tip box cannot be worn in a vest?
It has many options for different screws
Why we need them all?

We do not need them all for this task
Why we have all of them with us?
We have excess inventory

Value Stream map allows Lasi & Idea to start measuring the development of the glued glazing maintenance projects by having quantitative data of the process. Besides the quantitative date it was decided that qualitative advice to remove certain waste was attached as a note to each waste. Some of these notes have a ready solution to remove the waste it is attached to.

4.2.1 Current state of the process

Qualitative perceptions in the Value Stream map reveal that the biggest problems lie in the design of the glued glazing maintenance system. The process has been built to serve the manufacturing worker, not the customer. The glasses are being delivered to the workshop, what ideally from Lean perspective should be the other way around; the workshop should come to the customer. The waste of transporting the glasses causes supporting waste around the transportation, in packing and unpacking.

Other perceptions are that the tools used for the task are excessively too powerful, large and in too many as well as they are not organized enough.

The most surprising results have been noted from the quantitative results. Lasi & Idea have earlier perception were that there is no, or very little defects perceived by the customer. This has led to a misleading assumption that the process has very little defects. However, understanding that the excess glue finishing steps made mostly during re-installing is not really adding value to the customer, drastically changes the situation.

The quantitative data (seconds of each activity) allows for presenting statistical data that confirms the perceptions made during Value Stream mapping. Less than 32% of the whole glued glazing maintenance bring value to the customer. 10.9% is waste, what was often present in the task, but in relatively short moments. Perceptions in the Value Stream map reveal that most of this can be relatively easy to remove, by rightsizing accessories and tools, as well as introducing more standardized approach to the maintenance steps. Like perceived during the Value Stream mapping, mostly process design related issues cause waste that occupies over 57% of the time spent for the glued glazing maintenance.

This creates excellent opportunity to improve the maintenance process as there is less problems, but much more occupied time amongst the needed non-value adding waste.

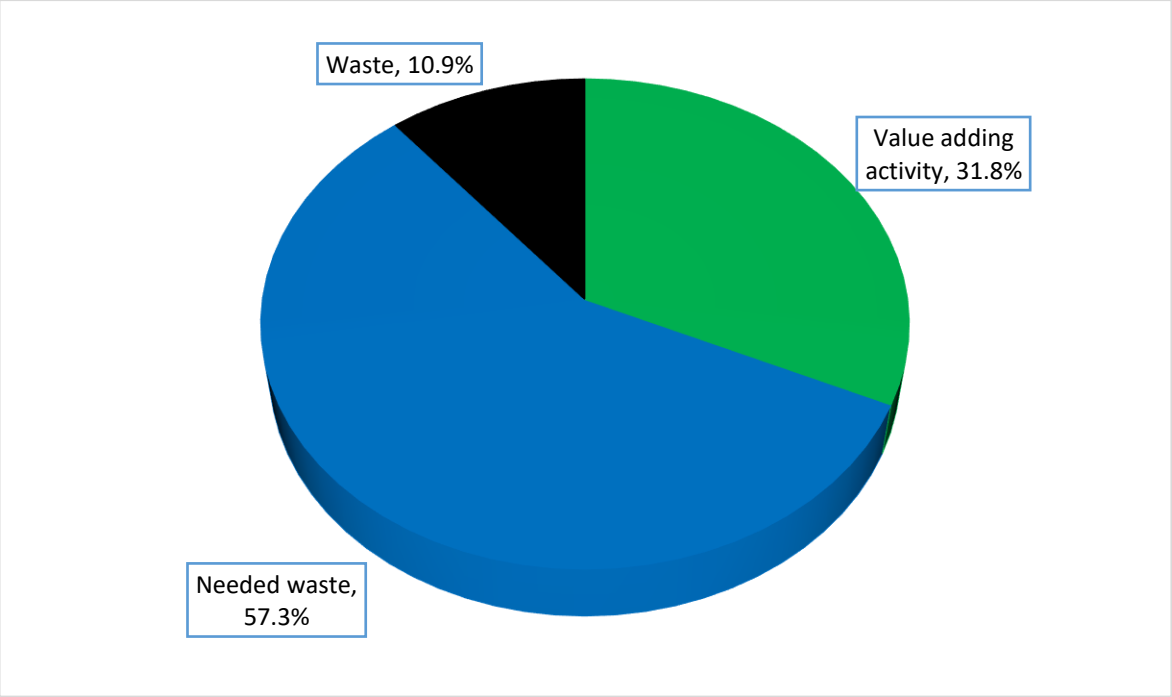


Figure 12. Value analysis

The author decided to build a numeral waste matrix (appendix.2) rather than a common style current state macro map. The matrix was chosen because the data in the Value Stream map consists of very detailed information of the activity, but does not present simple holistic way of the current state. The matrix measures the most important metrics from the Value Stream map and updates itself, unless categories are not increased or removed.

- Waste per category in seconds and percentage
- Waste per each of the seven-waste group
- Value adding time per category
- Takt time per category
- Total waste in seconds
- Total waste in percentages
- Takt time in total

4.2.2 Selecting process metrics

The author strongly recommends of adopting process state metrics that are as automated as possible. Filling and calculating the metrics tend to not be updated frequently enough. This leads to outdated data or even worse, misleading data. The pre-suggested KPI´s presented in chapter 3 would not be the best fit for the process analytics. However, the new

KPI´s should present the required information to answer the questions. How long does it take to complete the job, every time? How can we minimise the extensive communication in projects (not researched in this thesis as it happens mostly before and after the maintenance)? How can you achieve the shortest lead time of the maintenance project?

The author suggests adopting process management system and to constantly measure the following metrics:

- Cycle time from different steps of the process
- Lead and cycle time of the process
- Time used for repairing defects
- Cumulative flow of the maintenance

These metrics can be used to start improving the process towards the customer oriented metrics in chapter 3.

4.2.3 Focus to remove right waste groups

In this case by spending few moments with the waste matrix (appendix 2.) it is possible to see the percentages of each waste group. It is often the case that the highest percentage groups create more waste around them.

By inserting the data into a form of Pareto chart we can use The Pareto analysis. According to the theory approximately 80% of the waste is created by 20% of the waste groups. Before conducting it, we did suspect that waste group, 3. unnecessary transportation would create part of the other wastes found.

What can be seen from the Pareto chart is that Lasi & Idea should focus to start continuously measuring defects in the glued glazing maintenance process and enhance the design to serve a flow unit, the customer and build the workshop as near as possible to the origin of the glasses. Also, the new design process should have quality built in.

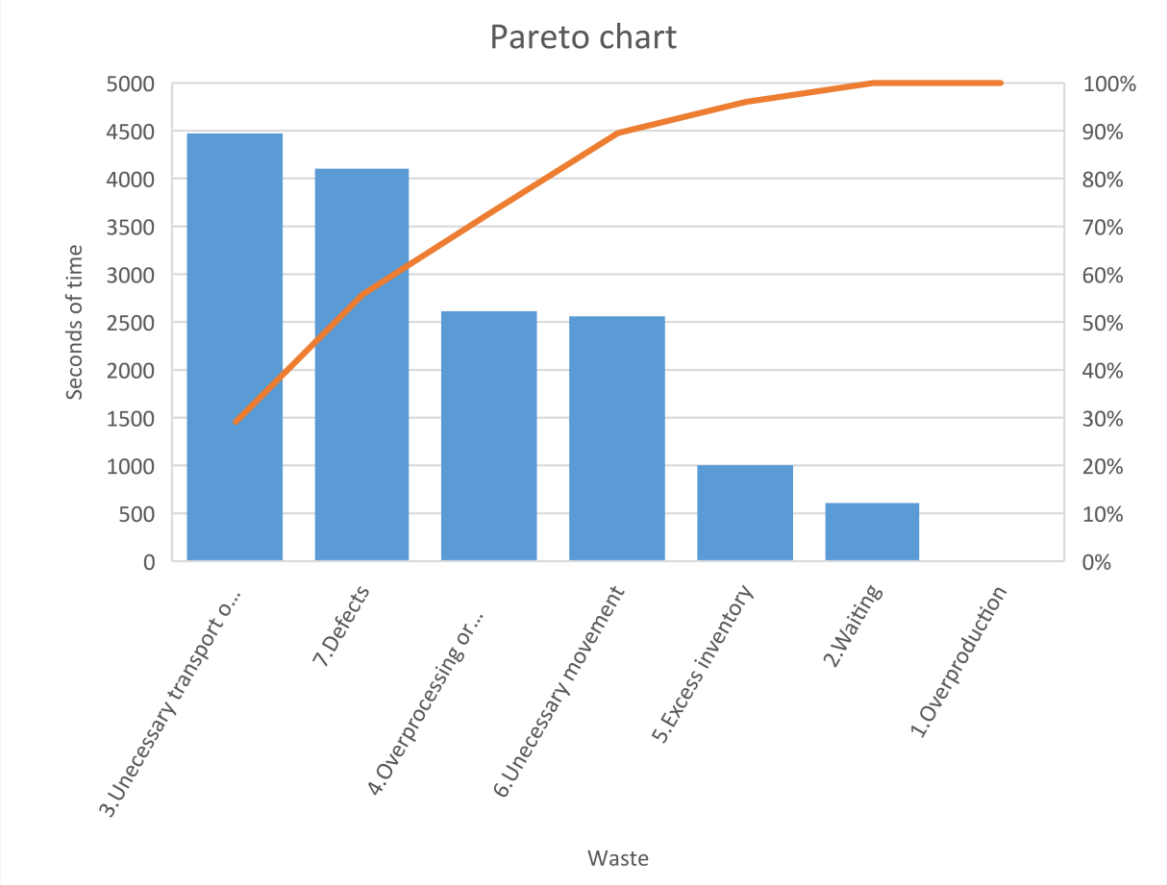


Figure 13. Pareto chart analysis from The Value Stream map

4.3 Minimising unnecessary movement through 5S

Unnecessary movement occupies 17% of the wastes. This is enough to consider implementing Lean 5S to the everyday doing in the company. Sorting out the inventories and relocating only the necessary tools as near as possible in the production line is suggested. The tools should be always within the reach in a shadow wall, hanging safely and quick to grab when needed. In this case light and mobile shadow walls are likely to offer the most benefits. These can be made from plywood and tools are drawn into the board where they belong to, like a shadow. A visual planned factory map of the manufacturing lines should be drawn, according to its tools. This way the production lines can be set up same way every time. The first step is setting up the production line, filming it, conduct a Value Stream map and analyse it.

5S can be used in removing and re-installing steps as well. The excess inventory should be removed, and tools chosen to be as light as possible. Power tools left out, screw bit number decreased from 80 to 18. All the tools should be signalled with a matching colour of vest tool holders and pockets. When tools are worn there will be no need for extra

packing and unpacking. This will also decrease inventory related waste and need for constantly climbing up and down stairs.

The system needs managing. Inspections need to be conducted every Friday. Team rewarded when conducted as planned. In case poor results, it should be solved with the people responsible for the task and practised.

4.4 Heijunka – Constant flow throughout the project

Scheduling the project to maintain continuous flow is very important. Smoothening Mura will need a well thought design and disciplined management throughout the process. Firstly, it will be impossible to find the optimal levelling without acquiring awareness of the maintenance need in each apartment. Each glazing in every apartment go through the same glue maintenance, but the additional repairing in the balcony varies. This consists of replacing broken components, levelling glass guiding profiles and adjusting components for smooth safe and durable use. Takt time of glued glazing maintenance (TTGL) must be summed with the predetermined time needed for additional repairs (TTAR). As the additional repairs will take place during and after the glue maintenance, if additional repairs cannot be made in time, it must be taken off from the schedule and repaired outside the schedule. This is important, as if continued to repair over predetermined takt time it will cause muri; overburden to available resources and with overburdened people rapidly decreasing quality. It is possible to take small delays into an account, by adding 10 percent buffer to the needed takt time to complete one apartment. A function of (TTGL+TTAR)*10% can be used to determine the needed time slot per apartment.

To acquire the necessary information the extra repair needs must be surveyed during first steps of the project. The repair time is to be set by management together with the crew designated to do the additional repairing, in spirit of Genchi genbutsu, go and see for yourself to thoroughly understand the situation. The difficult, most uncertain repairs must be tagged as high priority (H), whereas the balconies with no additional repair needs tagged as low priority (L) and normal priority (N) for simple additional repair. According to Heijunka, the high priority repairs should not be scheduled after each other. To implement Heijunka to glued glazing maintenance project Lasi & Idea management should be aware of the percentage of each type of additional maintenance need balcony (L, N, and H). One day of the week should be left unscheduled for the tools maintenance (M), possible tasks taken aside from the flow (BLG) and for Kaizen events to support continuous learning (K). The Heijunka model suggested for average maintenance project, per team, should be laid

the way that the possible difficult maintenance task should not be followed by another difficult one.

Table 6. Heijunka in Lasi & Idea weekly scheduling

Monday	Tuesday	Wednesday	Thursday	Friday
L	N	L	H	M, K, BLG

As heijunka determines also the process evenness, it is reasonable to conduct a bottleneck analysis. Bottlenecks gather waste around them, as before and after a bottleneck, a build-up of work-in-process (WIP) inventories can be always found. Any bigger unevenness will stop the flow. There are two ways to act if a bottleneck is found, either by improving the speed of the bottleneck or slowing down other process steps to match the bottleneck speed. Speeding up a process step can be done by improving the step or, by allocating more resources to it. There is often a limit how many employees, for example, can be allocated around the same workstation. Bottleneck analysis is conducted by presenting a Takt time of each process step.

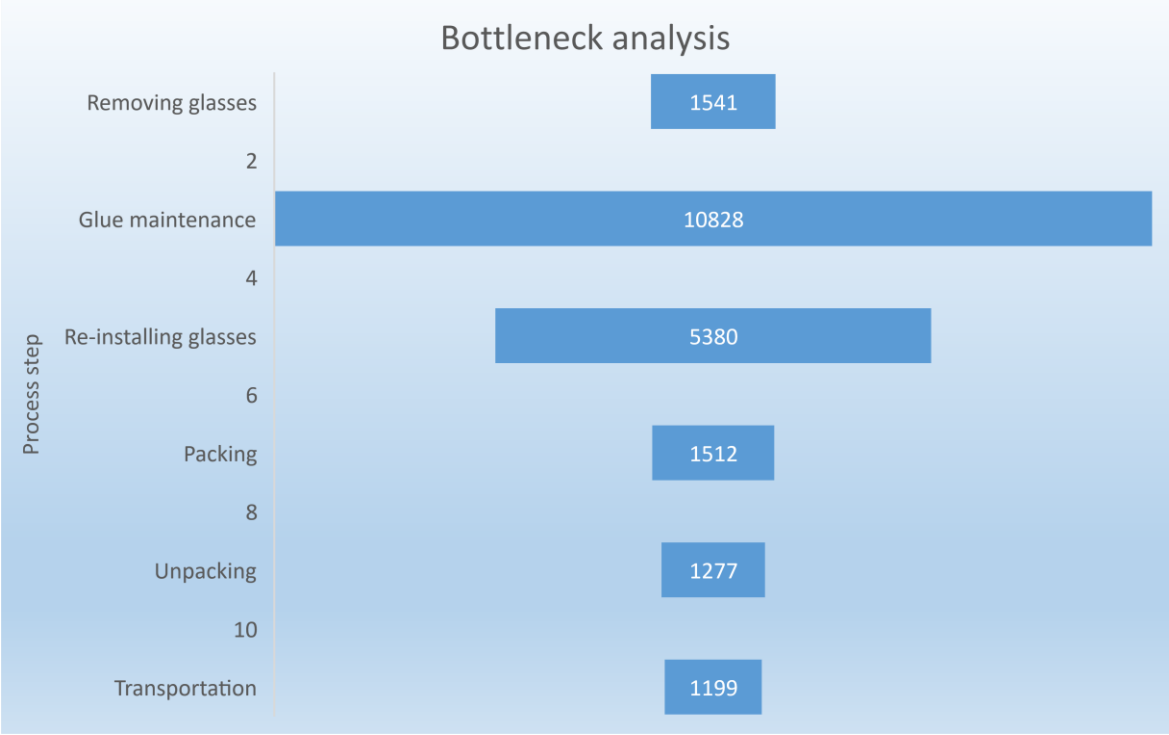


Figure 14. Bottleneck analysis

As we can see in the bottle neck analysis (figure 14) the glue maintenance process step is the biggest bottleneck of the process. It has most of the waste 1 hr and 23 minutes and it is causing 1 hour and 12 minutes of waste to the next step (appendix 2). The suggestion

based on the bottleneck analysis is to focus on improving the glue maintenance step by eliminating waste and redesigning the glue maintenance process.

4.5 Kanban as part of everyday management and communication

One of the tools that the author has had change to get introduced during the thesis process is a Kanban tool (kanbantool.com). It works like a regular whiteboard, but online. Kanban tool has a wide range of selections and can be modified to fit diverse needs. The online tool does not only make all the users involved in managing the process, but also creates an easily sharable platform to create cards with checklists, attached files and desired text. The cards can be pulled along the predesigned board, indicating the current state of the process.

The tool creates a web address and can be entered by anyone given passwords. It synchronises with calendar and can be used to show real time process development for the customers. It could provide help for the communication and integrate working instructions and management into a system that also gives valuable data metrics:

- Breakdown chart with selected depth
- Lead and cycle times
- Cumulative flow
- Changelog

It integrates perfectly with Heijunka, as cards can be allocated to certain worker. Also, the level of difficulty and priority can be predetermined.

4.6 Removing excess inventory and adopting JIT

During the gluing it was noticed that some part of the glue in the inventory had been out dated. The manufacturer (Sika) states that it could affect to the snap time by increasing it. This is a problem and mainly present because of the large batches ordered from Sika Switzerland, because of the lower costs of product. The other chemicals used in the process come from AT-Tuote Finland and Joint-Nauha Oy Finland. Sika offers similar product that is being used as a surface seam silicone Bostik. The author suggests focusing the purchasing to the Sika Finland and to negotiate a three-box contract with them. Sika would be responsible for holding a box always stored for Lasi & Idea with a sticker who to contact and how to get more as rapidly as possible.

Lasi & Idea needs to predetermine the usage of the two-component special glue made for glass and metals and to have two of the boxes that each lasts for two weeks to month, not two years, which is the normal best before date.
This way the amount of investment into to glue would be decreased, inventory decreased, and the possibility of outdated expensive glue being thrown away eliminated. Other positive effect would be the simplifying the purchasing, as more volume would come through Sika Finland and at least one, possibly two suppliers could be decreased. This could be used as a leverage option in negotiating the contract, but it would also help simplify purchasing.

5 Conclusions

The further the project has developed, the more it has become clear, how much potential there is still to improve. It is truly amazing and inspiring to realize what kind of continuity Lean offers to its engineers. The author is pleased to have been part of the first steps of Lasi & Idea´s Lean journey.

Before starting the thesis project, there was a doubt that there was waste in the glued glazing maintenance process. However, there was no clear goals how to start removing waste and why the waste was there. When the batch was lowered to customer oriented minimum, one balcony, the problems started being more visible. It must be said that this one balcony that contains 5 glasses is still a batch, a fake flow. The design of the process is resource efficient and therefore a single unit flow was not tested. The single unit data can be retrieved from the Value Stream map due to the detailed manner it was conducted.

The author believes that with the analysis of the acquired quantitative data and the suggestion how to approach the next step of Lasi & Idea´s Lean journey will give Lasi & Idea the opportunity to focus on the three selected waste groups and to change the process design from resource efficiency to flow efficiency. Author suggest Lasi & Idea to adopt a Kanban tool (kanbantool.com) in wide use to the everyday management and communication. The software also measures valuable metrics needed for improving and controlling efficient flow. Then measure again plan, do, check, act.

Table 7. Selected waste groups to focus with methods

Waste group	3. Unnecessary transport or conveyance	7. Defects	6. Unnecessary movement
Suggested method(s)	- Move workshop to customer - Create single cell workshop if possible - Create singlel unit flow	- Re-design new glue process - Improve machine effectiveness - Eliminate waste	- 5S - Visual factory - Remove and right-size excess over-sized tools

The original plan was to continue further with the analysis and to provide a future state map and test it, benchmark the new model against the old one. However, two of the major wastes were caused mostly by the design of the process, resource efficiency thinking of transporting large batches to the workshop and a glue process causing much defect to the next process step to be fixed. To achieve short lead times with one customer, the workshop should be much downsized to serve one flow unit, and brought to the customer. The second step in the new, better design, is rebuilding the glue process to have quality built in the glue process. The Value Stream map (appendix1) and the waste matrix (appendix 2) will provide the necessary information to start building efficient glued glazing maintenance process.

5.1 Product (PO)

The product of this thesis is a Value Stream map (Appendix 1). The Value Stream map is created with Microsoft Excel. The Waste Matrix (appendix 2) updates itself from the Value Stream map. It allows Lasi & Idea to begin improving the glued glazing system maintenance service, by executing a countermeasure to eliminate, or to reduce, a specific wasteful activity. This way it is possible to use the tool to measure the state of the process lead time, process step Takt Time, work station balance (Mura), value-non-value-waste relation. When the new Kaizen event is held, an improved process model can be made with the Lasi & Idea team, aiming to create a theoretical Future State map and by creating instructions to execute the new process design.

The Value Stream map also provides qualitative perceptions. The qualitative data was not used in this stage of the analysis, but is likely to provide valuable data in later stages, when the more visible problems have been solved, and the smaller problems become more unclear.

5.2 Gemba

Team management needs to be working from the same location where the value is created, and the work executed. This enables fast communication between the maintenance unit and the management. When the management is present at the site where the work is conducted, it is likely to bring lot less waste in waiting for new orders if something unexpected occurs. After adopting new systems like 5S the Gemba walks must be scheduled and evaluated to bring desired results.

5.3 Anchoring Kaizen to organization culture

Anchoring Kaizen into the organization culture is very important. This should be taken into the consideration when planning weekly schedules. The author suggests that every person involved in the glued glazing maintenance are demanded to start using the Kanban tool provided by Lasi & Idea. In this way every person is involved with the management system, aware of the current state of the process and work towards common goals. The author believes that the common work towards management will create more interest in kaizen events and personal or team Hansei feedback sessions.

Kaizen is one of the most important and very complicated philosophy of Toyota Production System. The author suggests having Kaizen events often, not as large as the topic in this thesis, but small steps, every week. Continuously.

5.4 Personal growth

Finally, the personal learning of the author could be described as an eye opener. The author has been involved in various construction projects. They follow a very different pattern where the strong plan building plays major part in the success. Thesis as an academic process has been totally different by its nature. The strong plan does help, but it does not make change to the continuous revision and re-writing, finishing something, just to re-do it again. This kind of going back and forward process is something totally new for the author. Partly it can be due to the enormous amount of Lean literature and how it has

been interpreted by different authors, coming from diverse cultural and organisational backgrounds. There must be a learning curve in writing studies. What the author did know before this study, has become A Socratic Paradox; “I know, that I know nothing” (Socrates).

Digging deep into Lean theory and being in control of a Kaizen event for the first time, the author has learned a lot how to apply Lean in research methods, to choose supportive tools for analysing and to form conclusions based on the analysis. The previous view the author had from Toyota Production System, has really formed into a holistic view of how the elements connect to each other. The philosophical methods support each other tightly. For example, it is not possible to create a flow without the control of Kanban, or sustain it without Heijunka. 5S does not work without Visual Factory and also the absence of it cause Gemba walks to not give simple and fast results. Kaizen does not grow individuals if Hensei is forgotten and the organisation does not support learning without Hoshin kanri. Creating an efficient process from Lean perspective is just not possible, without the deep understanding of the connection.

The foundation for continuous learning have been made for Lasi & Idea, as well as the first steps of Lean knowledge for the author. The first Lean blueprints of The Efficiency in glued glazing system maintenance.

The foundation for continuous learning have been made in Lasi & Idea, as well as the first steps of knowledge for the author. The blueprints of The Efficiency in glued glazing system maintenance.

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Appendices

Appendix 1. Value Stream Map

	Removing 2nd glass hinge wheel 9:53-10:38	Removing 2nd glass 10:47-11:16	Removing 3rd glass hinge wheel 4:10-4:33
	45	29	23
Removing glasses from balcony			
	3	3	4
	3.Unnecessary transport or conveyance Transporting glass to apartment door-WIP-WIP-to truck 4:42-5:04, 5:07-5:12, 5:16-6:20	3.Unnecessary transport or conveyance Placing a glass to safe transportaion holder 6:54-7:13	4. Overprocessing Locking glass 1 upper wheel to prevent it from unwanted adjusting 7:18-7:58
	83	19	40
	6	3	5
	6. Unnecessary movement Climbing down the stairs to to put the screw holding 1st glass to unplanned WIP inventory on the balcony 3:42-4:00	3. Unnecessary transport or conveyance Moving unnecassary large stairs to make space to remove 1st glass 4:00-4:10	5. Excess inventory WIP inventory glass lowered on top of a shoe to free one hand to open front door to hallway. (Risk of defect) 5:04-5:07
	18	10	3

Removing 3rd glass 3:20-3:30, 4:45-5:12	Removing 4th glass hinge wheel 9:46-10:05, 10:20-10:34	Removing 4th glass 9:05-9:09, 10:47-10:55
10 27	19 14	4 8
3	6	6
3.Unnecessary transport or conveyance Walking back to the balcony 7:58-9:14 (Alternative way to remove this?)	6.Unnecessary movement Step up stairs to reach the wheel to be removed 9:26-9:33 (Unnecassary big stairs to shorten this time?)	6.Unnecessary movement Step down stairs 10:38-10:43 (Unnecassary big stairs to shorten this time?)
76	7	5
5	5	6
5. Excess inventory WIP inventory glass lowered on top of a shoe to free one hand to close front door. (Risk of defect) 5:12-5:16	5. Excess inventory WIP inventory glass lowered to lean against truck wall while holder is prepared (Risk of defect) (Improve cushion!) 6:20-6:54	6. Unnecessary movement Searching for glass marking equipment 7:13-7:18
4	34	5

Glue maintenance

Removing 5th glass hinge wheel

3:22-3:45

23

Removing 5th glass

2:57-3:03, 4:04-4:18

6 14

Removing 1st glass list

- heating 0:04-2:05
-Cutting silicone seal 2:25-3:00
-removing the list 3:20-4:33

First List to WIP Inv

1145

3

3.Unnecessary transport or conveyance

Transporting glass to apartment door-elevator-to truck 11:16 -11:48, phase1.2 0-0:56

Find way how to remove

96

4

4. Overprocessing

Marking glass number to indetify order (Processing)

1:13-1:47

34

3

3.Unnecessary transport or conveyance

Walking back to the balcony 2:13-3:20
(How to remove this?)

77

6

6. Unnecessary movement

Searching for fixed size 13wrench to remove hinge wheel from glass 2. Not found have to use adjustable wrench 9:14-9:26

12

4

4. incorrect processing

Adjusting wrench to right size 9:33-9:53

20

3

3. Unnecessary transport or conveyance

Moving unnecassary large stairs to make space to remove 2nd glass 10:43-10:47

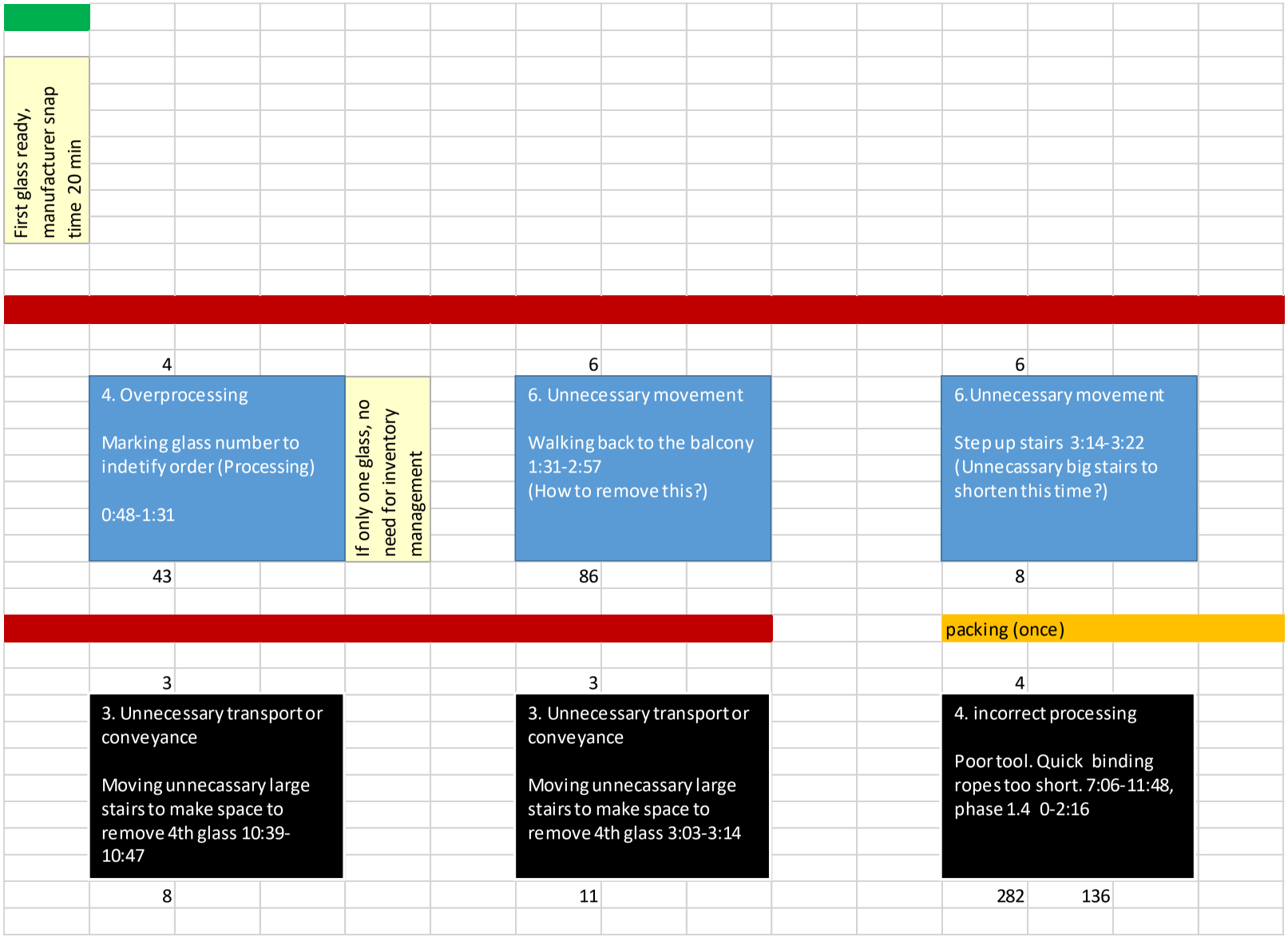
5

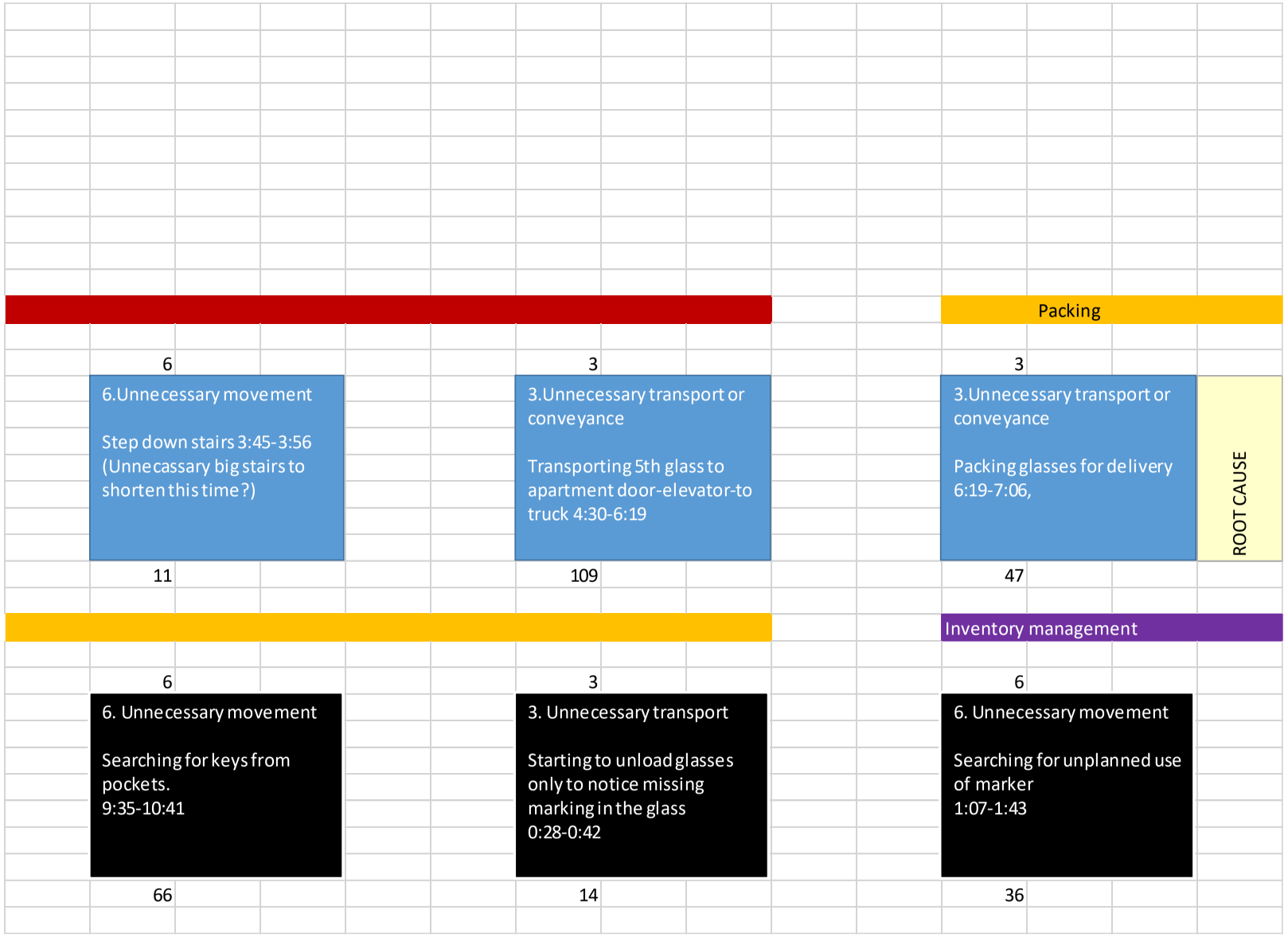
135

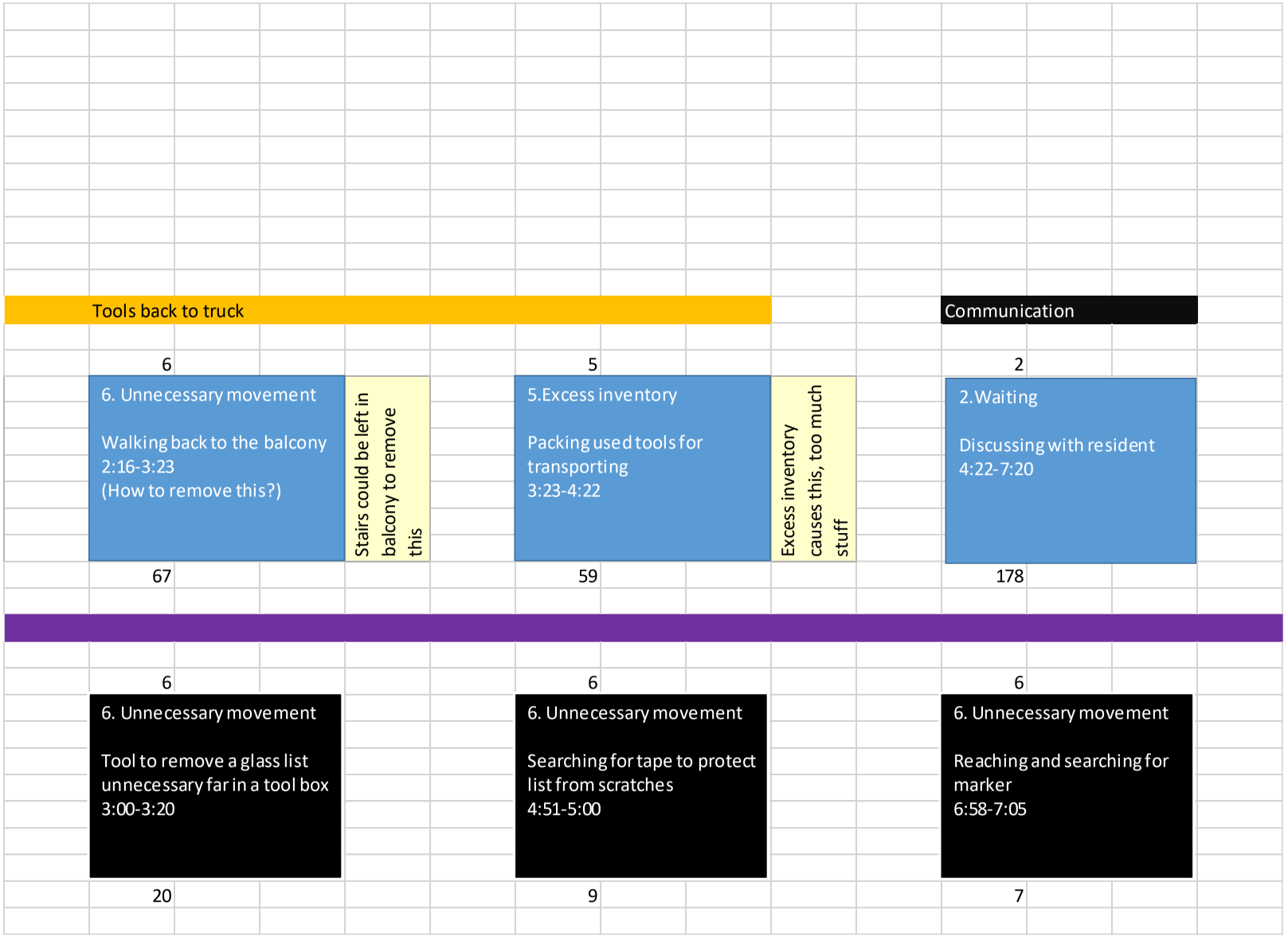
Multiplier of 5 used to apply for whole batch	Removing old glue 1st glass - Blade cutting 8:00-9:05, (3.1) 0:13-0:28, 0:38-1:02, 4:09-4:26	Multiplier of 5 used to apply for whole batch		Removing old glue 1st glass aluminium list - Grinding 10:30 - 11:48, (2.2) 0-4:26, 7:10-11:48, (2.3) 0-0:30, 3:08-5:22, 6:05-6:52	Find grinder blade life and standardize maintenance	Multiplier of 5 used to apply for whole batch	Removing old glue 1st glass - Cleaning fluid qpplying 7:08-8:35, (3.2) 6:37-6:47,	1 cleansing cloth/1 glass. Used multiplier 5 to whole batch		
	705			2775			485			
	6			6			6			
	6.Unnecessary movement Taking wrench from the pocket 3:40-3:43			6.Unnecessary movement Step up stairs 3:46-3:53 (Unnecassary big stairs to shorten this time?)			6.Unnecessary movement Step down stairs 4:33-4:40 (Unnecassary big stairs to shorten this time?)			
	3			7			7			
	4			3			4			
	4. incorrect processing Moving 2 glasses to gain balance on the glass holder 0:56-1:13			3. Unnecessary transport or conveyance Moving unnecassary large stairs to make space to remove 3rd glass 3:30-3:35			4. incorrect processing Poor tool. Adjusting wrench to right size 3:43-3:46, 3:53-4:10			
	16			5			20			

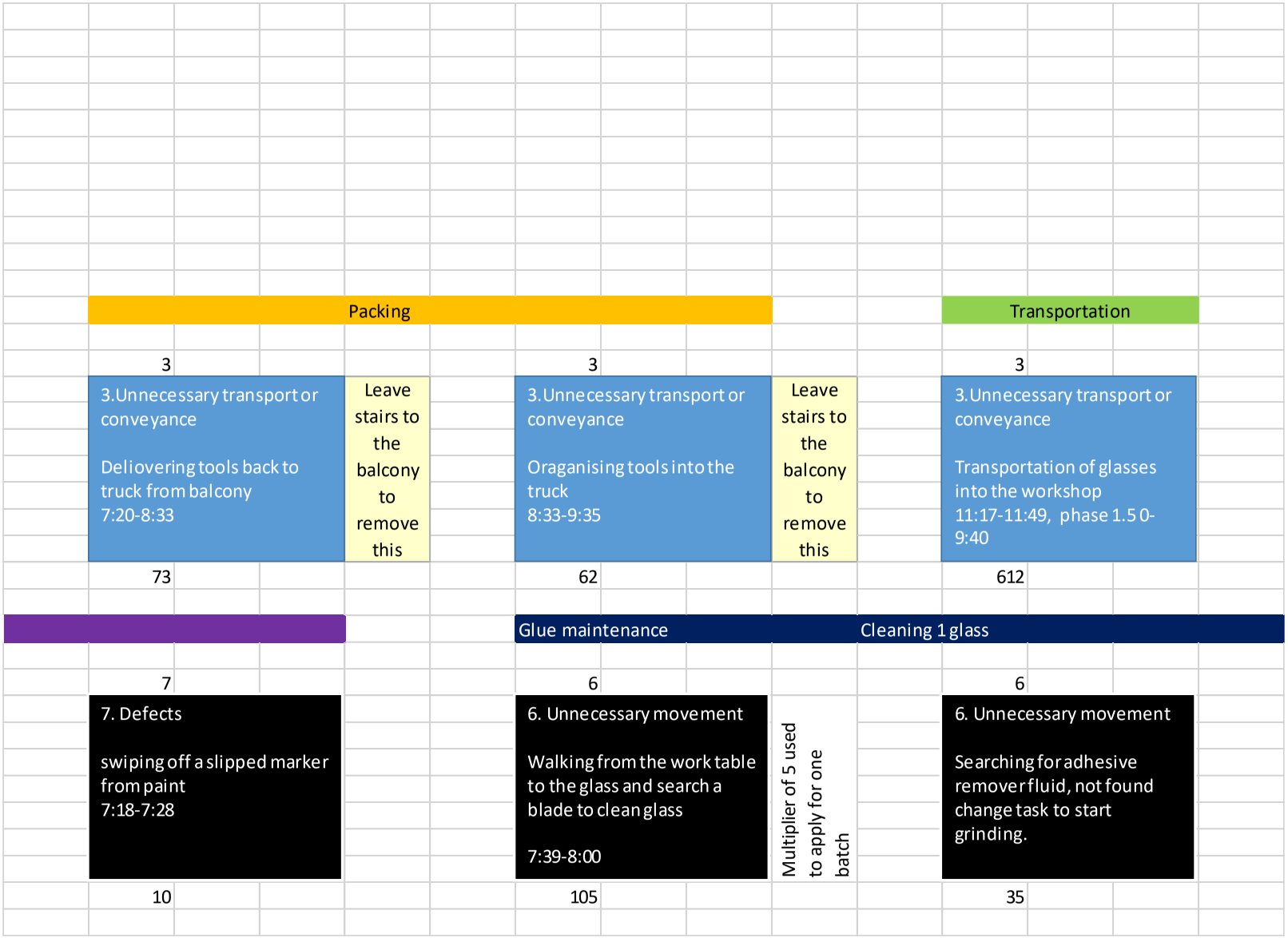
							Re-installing glasses	
	Glueing 1 glass - Activator applying 1:59-2:24 -Injecting glue 4:26--5:14	Multiplier of 5 used to apply for whole batch		Glueing 1 glass - Pressuring glued list 5:40-6:00, 6:31-7:23	Multiply glass by 5 to get whole batch		Re-Installing glass 5 - Re-Installing glass #5-2 7:20-7:42, 9:46-9:55	Multiply glass 5 by 4 to jump into glass #1 which is different
	365			360			124	
	3			4			6	
	3.Unnecessary transport or conveyance Transporting 3rd glass to apartment door-elevator-to truck 5:12-6:53 (How to remove?)			4. Overprocessing Marking glass number to indetify order (Processing) 7:05-7:45			6. Unnecessary movement Walking back to the balcony 7:52-9:05 (How to remove this?)	
	105			40			73	
	3			4			4	
	3. Unnecessary transport or conveyance Moving unnecassary large stairs to make space to remove 1st glass 4:40-4:45			4. incorrect processing Moving 3 glasses to gain balance on the glass holder 6:53-7:05			4. incorrect processing Moving marking to right place that was misplaced earlier (counts 3s for misplacing as well) 7:45-7:52	
	5			12			10	

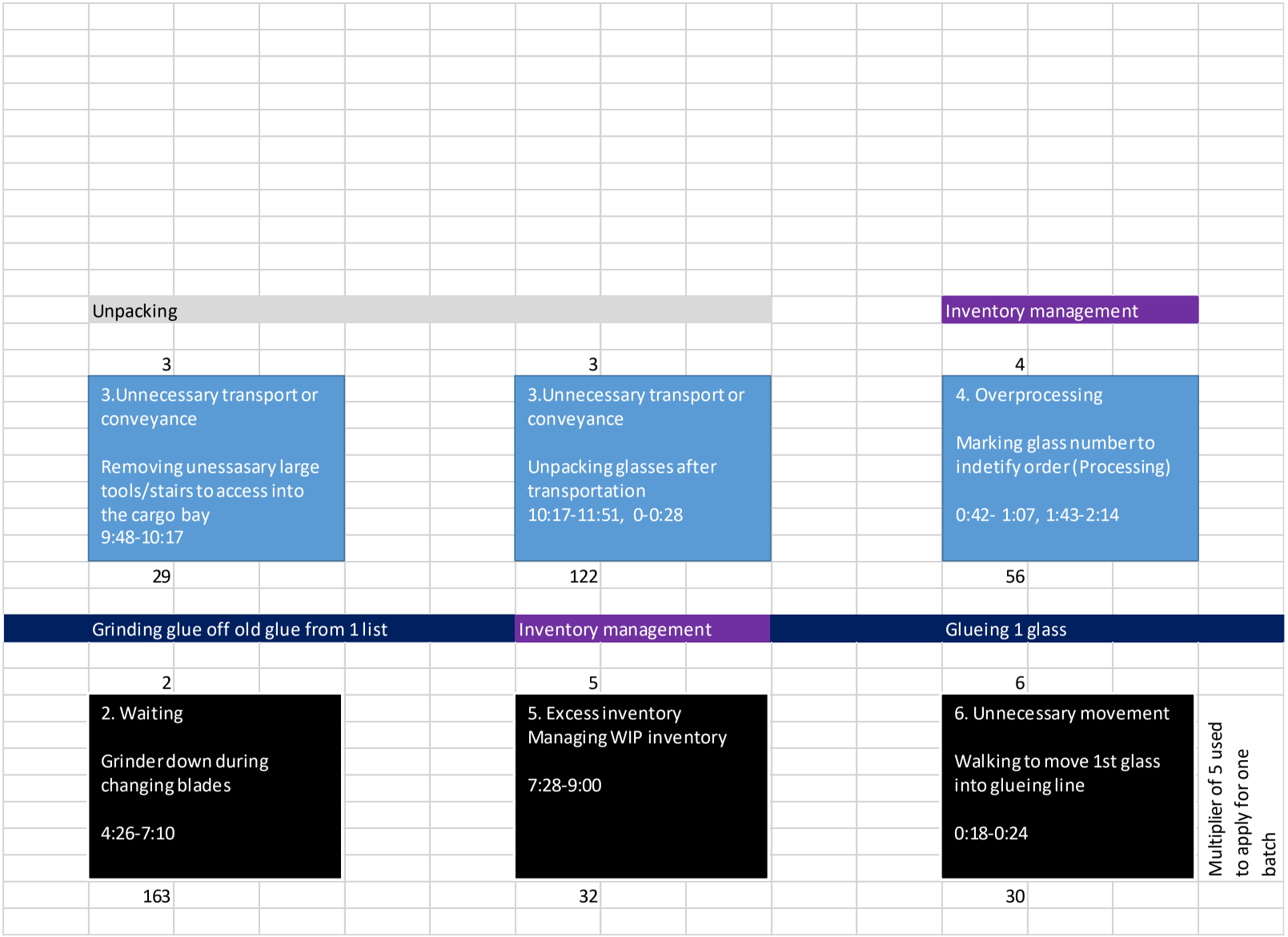
				Re-installing glasses							
	Re-installing glass #5-2 hinge wheel 8:03-8:30, 9:01-9:25	Multiply glass 5 by 4 to jump into glass #1 which is different		Re-Installing glass 1 - Re-Installing glass #1 9:04-10:51, 11:25-11:48, (4.11) 0-1:07			UV-Protective surface sealant (4.4) 3:30-5:17	Multiplier 5 used to apply for whole batch	First glass ready, manufacturer snap time 20 min		
	204			207			535				
	6			6			3				
	6.Unnecessary movement Step up stairs 9:19-9:30 (Unnecassary big stairs to shorten this time?)			6.Unnecessary movement Step down stairs 10:34-10:39 (Unnecassary big stairs to shorten this time?)			3.Unnecessary transport or conveyance Transporting 3rd glass to apartment door-elevator-to truck 10:47-10:48, phase 1.3 0-0:48				
	11			5			59				
	3			4			6				
	3. Unnecessary transport or conveyance Moving unnecassary large stairs to make space to remove 4th glass 9:09-9:19			4. incorrect processing Poor tool. Adjusting wrench to right size 9:30-9:46			6. Unnecessary movement Stepping down and up stairs as cannot reach loose wheel 10:05-10:20				
	10			16			10				


First glass ready, manufacturer snap time 20 min
4
4. Overprocessing
Marking glass number to indetify order (Processing)
0:48-1:31
If only one glass, no need for inventory management
6
6. Unnecessary movement
Walking back to the balcony 1:31-2:57
(How to remove this?)
6
6.Unnecessary movement
Step up stairs 3:14-3:22
(Unnecassary big stairs to shorten this time?)
43
86
8
packing (once)
3
3. Unnecessary transport or conveyance
Moving unnecassary large stairs to make space to remove 4th glass 10:39-10:47
3
3. Unnecessary transport or conveyance
Moving unnecassary large stairs to make space to remove 4th glass 3:03-3:14
4
4. incorrect processing
Poor tool. Quick binding ropes too short. 7:06-11:48, phase 1.4 0-2:16
8
11
282
136


Packing
6
3
3
6.Unnecessary movement
Step down stairs 3:45-3:56
(Unnecassary big stairs to shorten this time?)
3.Unnecessary transport or conveyance
Transporting 5th glass to apartment door-elevator-to truck 4:30-6:19
3.Unnecessary transport or conveyance
Packing glasses for delivery 6:19-7:06,
ROOT CAUSE
11
109
47
Inventory management
6
3
6
6. Unnecessary movement
Searching for keys from pockets.
9:35-10:41
3. Unnecessary transport
Starting to unload glasses only to notice missing marking in the glass
0:28-0:42
6. Unnecessary movement
Searching for unplanned use of marker
1:07-1:43
66
14
36


Tools back to truck
Communication
6
5
2
6. Unnecessary movement
Walking back to the balcony
2:16-3:23
(How to remove this?)
Stairs could be left in balcony to remove this
5.Excess inventory
Packing used tools for transporting
3:23-4:22
Excess inventory causes this, too much stuff
2.Waiting
Discussing with resident
4:22-7:20
67
59
178
6
6
6
6. Unnecessary movement
Tool to remove a glass list unnecessary far in a tool box
3:00-3:20
6. Unnecessary movement
Searching for tape to protect list from scratches
4:51-5:00
6. Unnecessary movement
Reaching and searching for marker
6:58-7:05
20
9
7


Packing
Transportation
3
3
3
3.Unnecessary transport or conveyance
Deliovering tools back to truck from balcony
7:20-8:33
Leave stairs to the balcony to remove this
3.Unnecessary transport or conveyance
Oraganising tools into the truck
8:33-9:35
Leave stairs to the balcony to remove this
3.Unnecessary transport or conveyance
Transportation of glasses into the workshop
11:17-11:49, phase 1.5 0-9:40
73
62
612
Glue maintenance
Cleaning 1 glass
7
6
6
7. Defects
swiping off a slipped marker from paint
7:18-7:28
6. Unnecessary movement
Walking from the work table to the glass and search a blade to clean glass
7:39-8:00
Multiplier of 5 used to apply for one batch
6. Unnecessary movement
Searching for adhesive remover fluid, not found change task to start grinding.
10
105
35


Unpacking
3
3.Unnecessary transport or conveyance
Removing unessasary large tools/stairs to access into the cargo bay
9:48-10:17
29
3
3.Unnecessary transport or conveyance
Unpacking glasses after transportation
10:17-11:51, 0-0:28
122
Inventory management
4
4. Overprocessing
Marking glass number to indetify order (Processing)
0:42- 1:07, 1:43-2:14
56
Grinding glue off old glue from 1 list
2
2. Waiting
Grinder down during changing blades
4:26-7:10
163
Inventory management
5
5. Excess inventory
Managing WIP inventory
7:28-9:00
32
Glueing 1 glass
6
6. Unnecessary movement
Walking to move 1st glass into glueing line
0:18-0:24
30
Multiplier of 5 used to apply for one batch

Unpacking		Glue maintenance		Removing 1 list	
3		6		6	
3.Unnecessary transport or conveyance Unpacking glasses after transportation 2:40-4:58		6. Unnecessary movement Reaching for a heat gun 0-0:04	Multiplier 5 used to apply for whole batch	6. Unnecessary movement Returning a heat gun 2:05-2:08	Multiplier 5 used to apply for whole batch
138		20		15	

		Inventory management			Glueing 1 glass	
4					7	
4.Incorect processing ROOT CAUSE Re-arranging correct caps to the cleaned lists to leave enough work space between 0:53-1:29	Apply visual factory to indicate exact places at once when deliverd from grinding. For whole batch	5. Excess inventory Moving stacked inventory to make space around glueing bench 2:50-3:00	Remove unneeded inventory	Multiplier of 5 used to apply for one batch	7. Defects Removing excess glue 6:05-6:20, 7:46-10:20	Makin sure there is maximum amount of glue contact results in excess glue coming out when pressuring list in its place
36		10			845	

1 Glass list cleaning from old glue			Inventory management		
6			4		4
6. Unnecessary movement Gearing up and picking tools 2:08-2:25	Multiplier 5 used to apply for whole batch		4. Overprocessing protecting glass list against scratches. 5:00-6:50	Takes too long, find faster way	Multiplier 5 used to apply for whole batch	4. Overprocessing Marking the removed lists to be able to track the glass 7:05-7:18	Multiplier 5 used to apply for whole batch
85			550			65	
Re-Installing Glasses							
6			3			5	
6. Unnecessary movement Walking to the wrong floor 11:35-11:48, (4.3) 0-0:12			3. Unnecessary transport or conveyance Moving unnecessary large stairs to re-install maintained glass 1:19-1:28, 7:42-7:49 , 10:00:10:05	Multiply by 4 to apply for glasses 5-2		5. Excess inventory Too many equipment and too big, takes time to organise into balcony 1:28-2:00	Multiply by 4 to apply for glasses 5-2
25			56			128	

1 Glass list clening from old glue

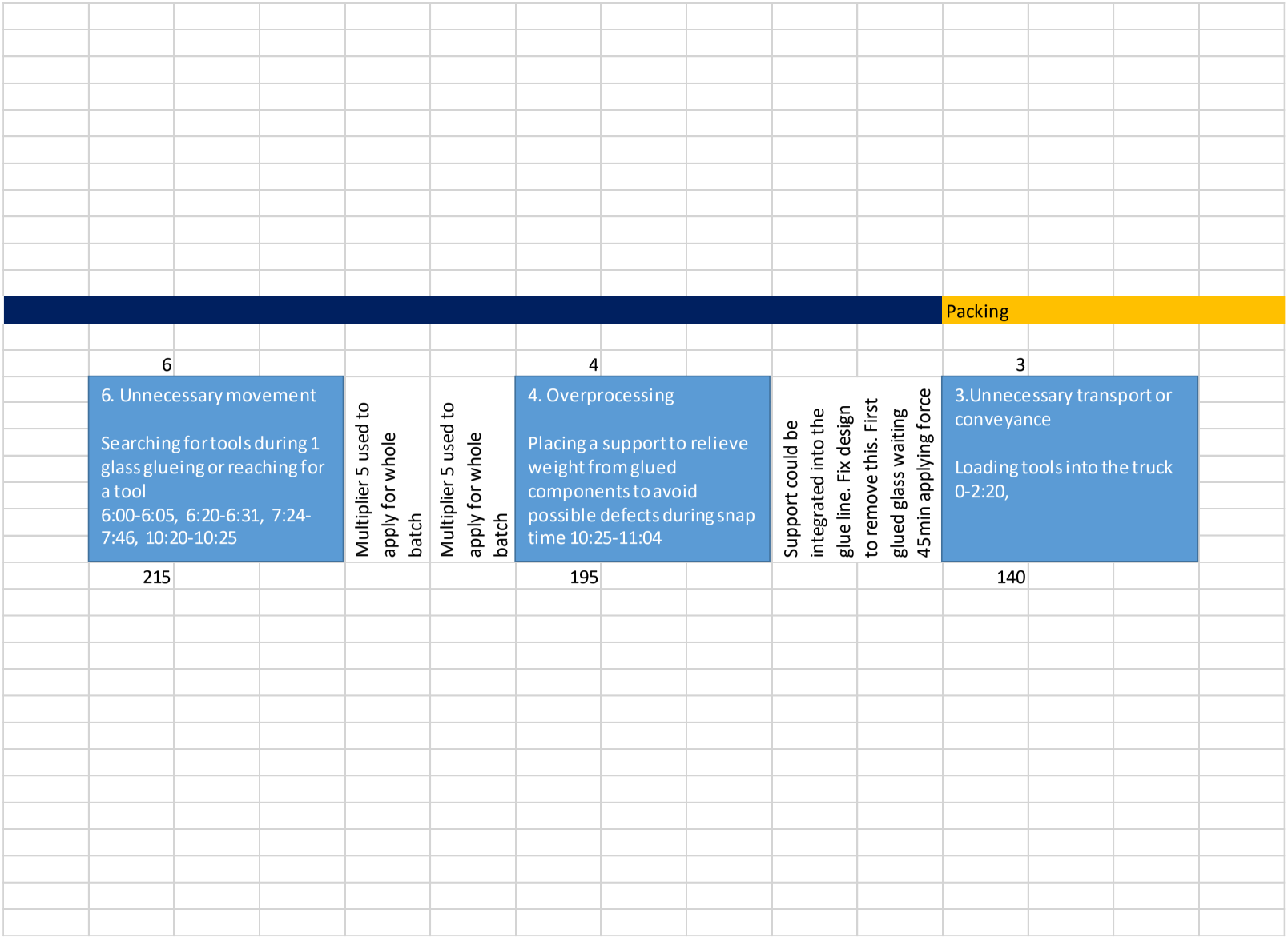
3	3. Unnecessary transport or conveyance Placing the list to the work table 7:28-7:39	55	Multiplier 5 used to apply for whole batch	
6	6. Unnecessary movement Picking multipurpose grinding tool and setting it up. 10:45-11:15	150	Multiplier 5 used to apply for whole batch	
6	6. Unnecessary movement Setting up vacuuming and pressure air to clean grinding product. 0:30-1:25,	275	Multiplier 5 used to apply for whole batch	
4	4. incorrect processing Poor tool. Adjusting wrench to right size 8:50-9:01	44	Use fixed size flat wrench instead	Multiply by 4 to apply for glasses 5-2
3	3. Unnecessary transport or conveyance Moving unnecessary large stairs to re-install maintained glass 10:51-10:56	5		
5	5. Excess inventory Tools needed on the box at the table, too much, too big 11:05-11:20		Find way to have everything needed in standardised vest holders. Take only needed gear!	

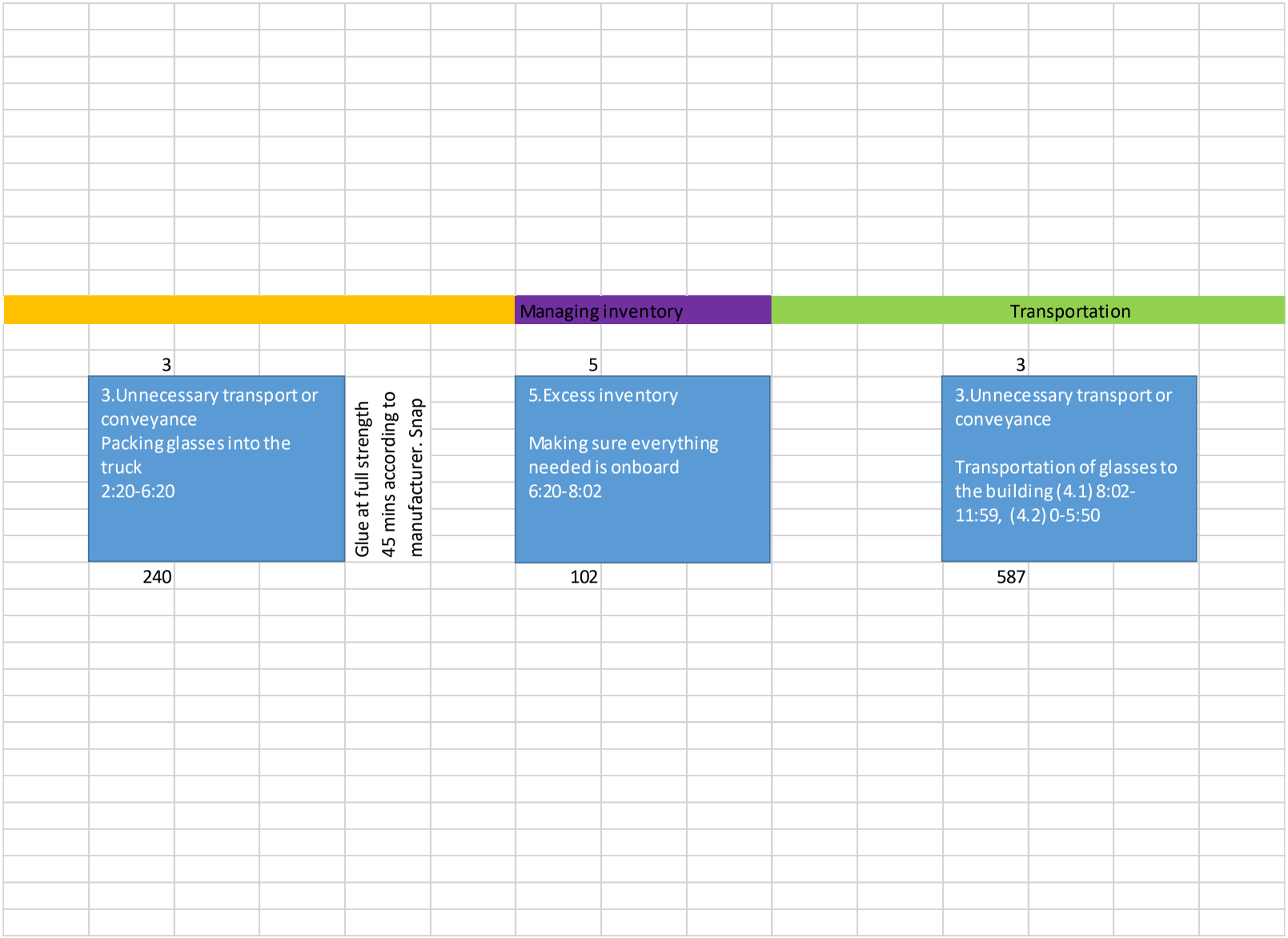
4					6						3				
4. Overprocessing Cleaning 1st glass grinding products 1:25 -3:04, 5:31-6:05, 6:54-7:24			Multiplier 5 used to apply for whole batch		6. Unnecessary movement Picking up grinder, lowering grinder during grinding, 3:04-3:08, 5:22-5:31, 6:52-6:54, 7:24-7:28			Multiplier 5 used to apply for whole batch			3. Unnecessary transport or conveyance Transporting the 1st list to the WIP invetory in right order		1st for glue. Last list cleaned end phase 2.10	Multiplier 5 used to apply for whole batch
815					95						300				
5					3										
5. Excess inventory ROOT CAUSE. Forgett something, but amount of tools to remember causes overburden (5.4) 0:20-1:42			Decreasing tools only to necessary , smaller and ligter to remove		3. Unnecessary transport or conveyance Moving unnecassary large stairs to re-install maintained glass 2:49-2:59										
82					10										

Inventory management	Cleaning 1 glass		Glueing 1 glass	
5	6		6	
5. Excess inventory Managing WIP inventory 8:28-8:58	6. Unnecessary movement Reaching for tool cleaning 1 glass 0:09-0-13, 0:28-0:38, 6:54-7:08	Multiplier 5 used to apply for whole batch	6. Unnecessary movement Setting up glueing 8:28-11:48, (3.3) 0-0:18, 3:00-3:08, 3:17-4:20	New glue patron was changed 50% time. For whole batch, do not multiply
30	140		169	

3					6					3				
3. Unnecessary transport or conveyance 1st glass from list removal holder to glue line 0:24-0:47			Multiplier 5 used to apply for whole batch		6. Unnecessary movement Seraching for tools during 1 glass cleaning 1:29-1:47, 1:54-1:59, 2:24-2:36, 3:08-3:17			Multiplier 5 used to apply for whole batch		3. Unnecessary transport or conveyance 1 Glass list from WIP to glue bench 2:36-2:50			First clean glass list from WIP to glue bench	Multiplier 5 used to apply for whole batch
115					270					70				

6					4					3			
6. Unnecessary movement Seraching for tools during 1 glass glueing or reaching for a tool 3:00-3:20, 4:17-5:23,			Multiplier 5 used to apply for whole batch		4. Overprocessing Injecting glue to make sure new patron components are getting mixed 3:20-4:25			Find a way to with supplier to remove this	For whole batch	3. Unnecessary transport or conveyance Glue bench back to glue line 5:30-5:40			Multiplier 5 used to apply for whole batch
130					65					50			


Packing
6
4
3
6. Unnecessary movement
Searching for tools during 1 glass glueing or reaching for a tool
6:00-6:05, 6:20-6:31, 7:24-7:46, 10:20-10:25
Multiplier 5 used to apply for whole batch
Multiplier 5 used to apply for whole batch
4. Overprocessing
Placing a support to relieve weight from glued components to avoid possible defects during snap time 10:25-11:04
Support could be integrated into the glue line. Fix design to remove this. First glued glass waiting 45min applying force
3.Unnecessary transport or conveyance
Loading tools into the truck 0-2:20,
215
195
140


Managing inventory
Transportation
3
5
3
3.Unnecessary transport or conveyance
Packing glasses into the truck
2:20-6:20
Glue at full strength
45 mins according to manufacturer. Snap
5.Excess inventory
Making sure everything needed is onboard
6:20-8:02
3.Unnecessary transport or conveyance
Transportation of glasses to the building (4.1) 8:02-11:59, (4.2) 0-5:50
240
102
587

	Unpacking													
	3					5					3			
	3.Unnecessary transport or conveyance Unpacking transportation rack 5:50-6:45					5.Excess inventory Moving stacked boxes, searching for tools needed in next task 6:45-9:49 ROOT CAUSE			Too much inventory not needed makes finding needed		3.Unnecessary transport or conveyance Unpacking and delivering unnecessary large tools to the balcony 9:49- 11:35, (4.3) 0:28-1:18			
	55					213					166			

2	3	6	
2.Waiting Waiting for resident to open door 0:12-0:28	3.Unnecessary transport or conveyance Unpacking and delivering unnecessary large tools to the balcony (4.3) 0:28-1:18	6. Unnecessary movement Walking back to the truck to deliver 1st glass to balcony 2:20-3:20	Multiplier 4 used to apply for glass 5-2
16	50	200	

Communication			Re-Installing glasses					
2	3		6					
2.Waiting Discussing with a resident of another to be maintained balcony 3:20-5:50	3.Unnecessary transport or conveyance Delivering glass 5-2 to balcony 5:50-7:20	Multiplier 4 used to apply for glass 5-2	6.Unnecessary movement Step up and down stairs 7:55-8:02, 9:42-9:46	Unecessary big stairs. Find more suitable lighter stairs	Multiplier 4 used to apply for glass 5-2			
150	360		44					

Communication

Re-Installing glasses

2

2.Waiting

Discussing with a resident
8:30-8:50

20

4

4. Overprocessing

Testing glass 5-2
9:25-9:42

68

Multiplier 4 used to apply for glass 5-2

6

6. Unnecessary movement

Walking back to the truck to deliver glass #1 to balcony
(4.9) 6:05-7:03

58

3	4		6
3.Unnecessary transport or conveyance Delivering glass #1 to balcony 7:03-8:42	4. Overprocessing Removing tape that was used to lock wheel for glass #1 8:42-9:00		6.Unnecessary movement Step up and down stairs 10:56-11:05, 11:20-11:25
99	18		14

	Packing	Unpacking
4	3	3
4. Overprocessing Testing glass 1 1:07-1:40	3. Unnecessary transport or conveyance Delivering powerdrill to lock #1glass back to truck 1:40-3:15	3. Unnecessary transport or conveyance Delivering tools for glue stain removal and sealant adhesive to balcony (4.2)0-0:20, 1:25-2:49
33	95	104

Each glass should go into the hinge mechanism, other can be left to final inspection

Same time close the doors of the truck to prevent theft of tools. Close it when last glass out for less waste. Too large drill

Re-Installing glasses			Packing
7		7	5
7. Overprocessing Fixing glue defects, tidying up glue seals, removing protective taping, markings 3:25-11:48 (4.4) 0-2:20	No visible glue stains can be present. Find way to prevent them so that glue durability do not suffer	7. Overprocessing Due to previous waste. Trash must be collected and bagged(4.13) 4:45-5:21	5.Excess inventory Organising tools on the table used at different stages in the balcony 7:20-8:40, 10:50-10:59
3215		36	89

Communication	Packing	Communication
2	3	
2.Waiting Discussing with a resident 8:40-9:25	3. Unnecessary transport or conveyance Delivering tools back to truck 10:59-11:41, (4.14)0:36-1:24, 2:00-3:40	2.Waiting Discussing with a resident 1:24-2:00
45	142	36

Appendix 2. Waste matrix

Waste	Category total s	1	2	3	4	5	6	7	Value adding	Takt time (T/T) s
Removing glasses	1269	0	0	678	251	60	280	0	272	1541
Glue maintenance	4993	0	163	590	1661	0	1734	845	5835	10828
Re-installing glasses	4310	0	0	530	163	225	141	3251	1070	5380
Packing	1512	0	0	813	418	148	133	0	0	1512
Unpacking	1277	0	16	664	0	397	200	0	0	1277
Transportation	1199	0	0	1199	0	0	0	0	0	1199
Inventory administration	377	0	0	0	121	174	72	10	0	377
Communication	429	0	429	0	0	0	0	0	0	429
Total	15366	0	608	4474	2614	1004	2560	4106	7177	22543
Total %	100%	0%	4%	29%	17%	7%	17%	27%		